The Blast Furnace and Steel Plant

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Volume XIV JUNE, 1926 Number 6

CONTENTS

Manufacture of Charcoal Iron at Mysore 250
The Mysore Iron Works Is the Only One of Its Kind in India to Burn Charcoal for Manufacture of Pig Iron—Fuel and Ore Are Conveniently Located
By A. P. SOM

Cyanid Accumulation in the Blast Furnace 254
Cyanid Accumulation Has Been Found Sufficient to Account in Vaporization for Over 30 Per Cent of the Coke Burned to Keep the Hearth Hot
By RICHARD FRANCHOT
Part II

Commutation Troubles in D. C. Machinery 257
The Cause and Elimination of 20 Different Kinds of Sparking Are Explained in Detail by the Author in This and Two Preceding Articles
By EARL B. STAVELY

Review of Rolling Mill Literature 261
This Review Covers Both American and Foreign Rolling Mill Literature Published During 1925, and Is One of the Most Comprehensive Ever Compiled
By RICHARD RIMBACH

General Principles of the Beneficiation of Iron Ores 265
By T. T. READ
Part II

Measuring Drawing Properties of Metals 275
The Authors, by Co-ordinating Their Laboratory Tests with the Results of Actual Drawing Operations, Have Endeavored to Determine the "Drawability of Metals"
By WM. S. MONTGOMERY, JR., and E. RAY ENDERS, JR.

Protective Coatings for Metals 281
The First of a Series of Educational Articles Dealing with Various Methods for Protecting Metal Surfaces Against Corrosion and Oxidation
By JAMES A. AUPPERLE

Low Temperature Carbonization of Coal 283
Consideration of Different Processes Operated in Direct Conjunction with Steam Boiler, General Furnace and Power Plant
By DAVID BROWNLIE

Beneficiation of Iron Ores 249
Safety Spats for Tin Plate Workers 256
Iron and Steel Tester Developed 260
Offers Research Work 273
Double Retort Boiler Stoker 273
New Use for Stainless Iron 273
Homestead to Install New Beam Mill 273
Safety Work in the Steel Industry 274
Heavier Rails to Support Heavier Traffic 274
Bethlehem Diesel Engines 280
Alan Wood Re-Elects Officers 280
Gas Fired Galvanizing Kettle 284
By F. X. METTENET
A. S. T. M. Announces Convention Program 285
New Equipment Section 286
Book Review 287
New Blast Furnace Blown In 288
Personals 289
Obituaries 289
Trade Notes 290
Coming Meetings 291
Trade Publications 292
High Speed Steel for Machine Knives 292

Published the first of each month by The Andresen Company, Inc.
Main Office—Thaw Building, 108 Smithfield Street, Pittsburgh, Pa.

President: L. L. CARSON Vice President: W. A. COVERT Secretary and Treasurer: M. M. ZEDER

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507 Donovan Bldg.
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Subscription Price:—In the United States, $2 per year; Canada, $2.50; all other countries, $3.50. Single Copy 25 cents.
Entered as second-class mail matter at Pittsburgh, Pa., under the Act of Congress, March 3, 1879.

The Blast Furnace and Steel Plant

Vol. XIV PITTSBURGH, PA., JUNE, 1926 No. 6

Beneficiation of Iron Ores

IN our January issue we devoted twelve pages to a survey of the important iron-ore resources of the world and in our April issue four pages to the deposits of Lorraine, Eastern France. These two articles were by O. R. Kuhn of the Donner Steel Company, Buffalo, N. Y. Mention was made of attempts to enrich the Lorraine ore by preliminary treatment. In the United States are large reserves of iron ores which must be dressed before they can be used in the blast furnace. In other words, these ores are of relatively low grade, but impurities must be removed before they become marketable. This process is called "beneficiation." The definition of this term is "reducing," but it means more than that—it is reduction or crushing and dressing of the ore to eliminate the impurities and incidentally raise the grade of the ore. Considerable thought and money have been spent in experimentation and in the erection of large plants to treat iron ores. According to D. E. Woodbridge, a specialist in iron ores at Duluth, there are 45 plants in the Lake region for beneficiating ores by washing, jigging, crushing, screening, magnetic separation, or by sintering; and 20 per cent of the ore shipments of the region (55,000,000 tons in 1925) were products of these plants. As this is an important factor in the iron and steel industry, we draw attention in this issue to the second part of a series of three articles on the general principles of the beneficiation of iron ores, by T. T. Read, until recently with the U. S. Bureau of Mines, and who spent some time in Minnesota studying this problem. The first part, which dealt with the iron minerals, the process of reduction of iron from ores, and the impurities therein, appeared in our April issue. In the present article, Mr. Read describes and discusses the methods of reducing and dressing iron ores. Before he does this, however, Mr. Read gives a lucid interpretation of the principles of reduction of iron from iron oxides and how a better grade of ore affects this reduction—by lowering the amount of fuel and fluxes required and, of course, the cost, also making the furnace run better. The greater part of this article is devoted to the effect of silica in ore on the cost of pig iron, the silica content of Lake ores, and the elimination of silica therefrom. Seven illustrations increase the value of this review of silica in iron ores. Following, is a discussion of porosity of ore, moisture in ore, and drying ore; and in this we find a case of washing ore to reduce its moisture content, an apparent paradox, but which operation actually converts an unsaleable ore into a readily marketable ore.

Manufacture of Charcoal Iron at Mysore

The Mysore Iron Works Is the Only One of Its Kind in India to Burn Charcoal for Manufacture of Pig Iron—Fuel and Ore Are Conveniently Located

By A. P. SOM*

THERE are at present two Steel Works and two Iron Works in India. Of the former, the Tata Iron and Steel Co., Ltd., is the more important and famous, and the other one is the Indian Iron and Steel Works, Ltd. The Bengal Iron Company at Kulti is the pioneer in the field of metallurgy in India. The Mysore Iron Works is of comparatively recent origin. Nevertheless it is a distinctive enterprise. It is the only State managed Iron Works in India, and secondly it is the only one of its kind in India to burn charcoal for the manufacture of pig iron.

The preliminary investigations for starting an Iron Foundry in Mysore were carried out in 1915 by Mr. Charles Page Perin of Messrs. Perin and Marshall, New York. In pursuance of his recommendations, a scheme for the destructive distillation of wood, Mysore having an extensive supply of wood from its wide forest areas, and manufacture of charcoal pig iron, was sanctioned by the Mysore Government in 1917-18.

The works aré situated at Bhadravati, on the left bank of the Bhadra River, a railway station on the Birur-Shimoga section of the Mysore Railways. The plant was designed by and constructed under the advice of Perin and Marshall between the years 1918-22, and the blast furnace was blown in early in January 1923.

For the first two years of operation, the necessary iron ore was drawn from Chattanahalli, a distance of 30 miles from the site of the plant. But this was a temporary arrangement pending the opening up for permanent supply of the Kemmangudi mines on the Bababudan mountain, some 25 miles south. The mean sea level at Kemmangudi, known as Upper Terminal is 4650 nearly, and the tramway from Bhadravati runs up towards it up to Thangebyle, a distance of 23 miles, and there is a fall of nearly 2,100 feet between the two places, which are nearly 3 miles distant horizontally. To lower the ore from the mine to the tramway, a "Monocable Ropeway" has been installed. It is supported on 36 trestles of heights varying from 10 to 60 feet nearly; is worked by gravity and has a carrying capacity of 30 tons per hour. The ore from the mine is delivered into buckets which travel with the rope at intervals of 36 seconds, 84 yards apart and are emptied by a very simple but ingenious automatic tipping arrangement at the unloading station. A bunker wall 200 feet long is provided for the storage of 14,000 tons of ore at the lower terminal.

Fuel for the carbonization of charcoal comes from the surrounding State forests of Kadus and Shimoga within a radius of 25 miles. About 350 square miles of forest area have been marked off for supplying wood and timber required for the works, and formed into a forest division. It is intersected by about 56 miles of tramways for transporting forest products as well as ores from the mines. The fuel is selected from about 20 varieties of wood, which have no timber value. It is billeted into specific sizes by manual labour and split in a saw mill erected near the factory and worked by electricity. The wood to be operated upon, is harvested, properly air-seasoned, decayed wood and heavy bark being rejected and none but sound solid wood above 2 inches diameter being used. All the undersized or rejected wood and bark including saw dust is used as fuel, giving no room for wastage.

The flux used is dolomite and is obtained from Shankargudda, 15 miles from Shimoga, while shells for neutralizing the pyroligneous acid are imported from Madras (South India) and burnt in a 5-ton lime kiln designed and erected at the site of the works. The latter expedient has been necessitated by the fact that limestone of sufficient purity has not been found to exist at a point within economic access of the works.

The plant consists of the following:

1—Saw mill plant, where the fuel as it comes from the forests is made ready for the process of carbonization.

2—The carbonization plant where the processes of carbonization and the recovery of pyroligneous acids are carried on.

3—The distillation plant, for the recovery of methyl alcohol, acetate of lime, tar and light oil. The average yield of different products in distilling 4,000 lbs. of the 20 kinds of Mysore fuel wood is as follows:

Methyl alcohol	7.03 gal.
Calcium acetate	165 lbs.
Settled tar	22 gal.
Soluble tar	8.19 gal.
Charcoal	1,278 lbs.

4—The crushing plant where the ore and flux are crushed before being delivered to the blast furnace, and finally,

5—The blast furnace itself, where the pig iron is manufactured from the ores.

The rest of the equipment includes a boiler plant with a capacity of 1,000 bhp., power plant, comprising three 350-kva. steam alternating current generator sets; water supply, consisting of three pumping stations, pipe lines and storage tank with a circulating capacity of 2,300 gallons per minute, foundry, pattern shop and machine shop, capable of handling all work in respect of repairs and replacements to the entire plant as well as for the manufacture of finished castings for the Indian market.

In the selection of the plant, the greatest care was exercised and practically every center in the United States devoted to the manufacture of the same products was visited and a decision based upon information thus gained, together with due consideration for Indian conditions, arrived at.

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*Jamshedpur, India.

The complement of rolling stock and track system consists of 10 miles of meter gauge railway, two 7½-ton and one 40-ton locomotives, ten 15-ton gondola wagons, one 10-ton locomotive crane, twenty 10-ton timber wagons, and three hundred 2½-cord or 5-ton charcoal buggies.

A description of the working of the various items of the plant right up to the point of actual manufacture, now follows.

At the far end of the wood yard, a little over a mile south-west of the main plant, is the saw mill, the machinery for which was supplied by Allis-Chalmers Manufacturing Company of Milwaukee. The mill has been designed to billet 300 tons of fuel per day of 10 working hours, 25 per cent of the fuel delivered by weight being 6 inches diameter or under, 45 per cent, 6 to 12 inches diameter, and 30 per cent over 12 inches diameter.

A steel structure 42 by 196 ft. comprises the main building with a lean-to on the billet delivery side, and a billet conveyor extension 42 ft. long. The building proper is a 2-3 storied structure. On the ground, or first floor of the latter, are the driving machinery, countershafts, friction drives and saw dust conveyors, the sawing machinery and auxiliary equipment being on the second floor, and the filing room on the top or third floor.

At either end of the mill, are sloping wharfs on which the wood delivered is unloaded. Midway between the wharfs are the car haul-up tracks to the mill. Thus the fuel, as it comes in from the forest on the 2-ft. gauge, can go to either wharf for unloading, or on to the car haul-up tracks and to the mills direct. The fuel brought in on the meter-gauge is delivered through the wood yard to the western wharf only, the empties being returned from the haul-ups to the siding at the bottom of the incline. There are two car haul-ups, which are winding drums operated by 40-hp. induction motors through a gear reduction and friction drive.

All fuel up to 12 in. diameter and 20-ft. long is dealt with by two sets of slashers, each of four 44-in. circular cut-off saws, while that above 12 in. goes to the band mill. The latter is driven by a 150-hp. motor at 375 rpm. with a peripheral speed of 9,000 ft. per minute, and is capable of dealing with 300 cu. ft. logs per hour. After having been cut to the required sizes in the mill, the fuel is loaded into the buggies and sent to the retorts or stacked in the wood yard.

In the carbonizing section the equipment consists of a retort house, 6 pairs of retorts, primary and secondary sets of coolers, cooling shed and transfer car. This plant is designed to carbonize 82,000 tons of wood per year, or 100 cords per day, as well as to recover 30,000 gal. of pyroligneous acid per day of 24 hours. The retorts selected are the standard type used in all the most modern plants. The employment of six sets of retorts admits of the closing down of one set each day of the week for the cleaning of the retorts and condensers which become dirty and choked after slight use.

The retorts and coolers which are composed of steel plates were built by Struthers Wells Company of

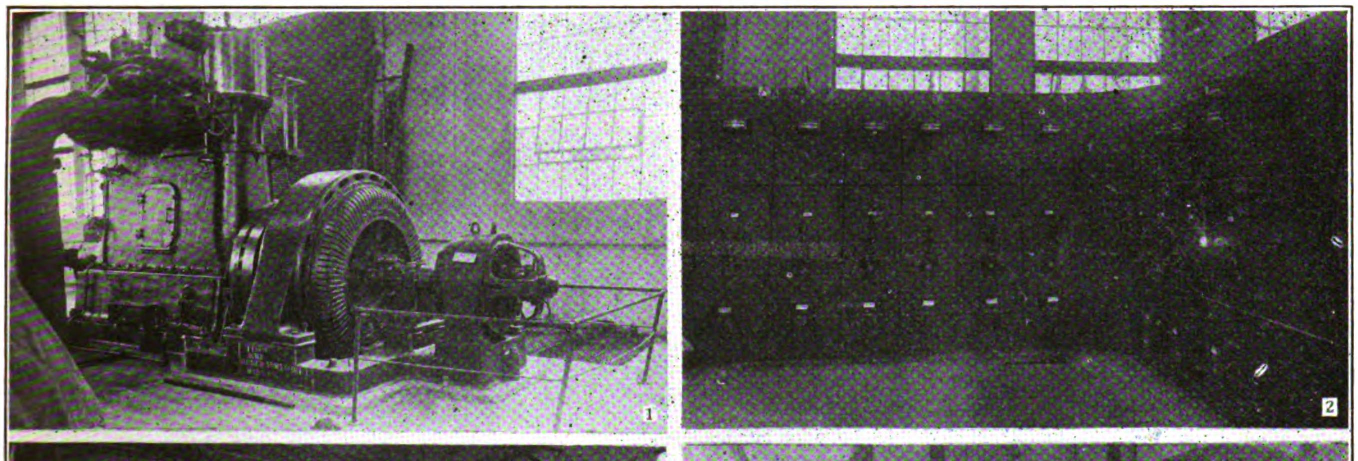

FIG. 1—Interior view of power house of Mysore Iron Works, showing alternating current generator set. FIG. 2—Interior view of power house, showing switchboard. FIG. 3—Interior view of power house, showing blast furnace uniflow blowing engine. FIG. 4—Interior view of hoist house for blast furnace, showing electrical and mechanical equipment.

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Warren, Pa. The building in which the retorts are housed is of structural steel, and is 274 ft. long by 76 ft. wide.

The general practice in firing the retorts is to first use the tar, wood or coal gas with a view to bring the temperature up as quickly as possible to breaking point, which usually occurs from 550 to 575 deg. F. Thereafter all other operative agencies are shut off, only the gas being allowed to remain, and the retort left to come down by the heat generated by exothermic action, the latter point being reached in from 5 to 7 hours after charging. Wherever possible, the temperature is kept below 650 deg. F., though if the wood is too dry, it rises to 900 deg. F. when carbonization becomes too rapid and a considerable portion of the by-products is lost, since the condensors are unable to handle the increased volume of gas thus set up. When the process of carbonization becomes accelerated in this way, the resultant charcoal is extremely brittle.

When the charge has been completely carbonized, it is transferred to the primary coolers where it is

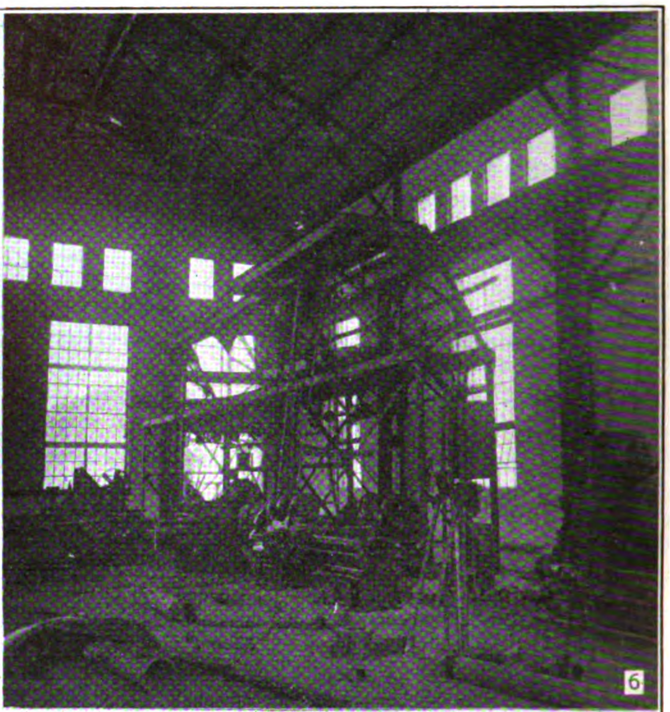
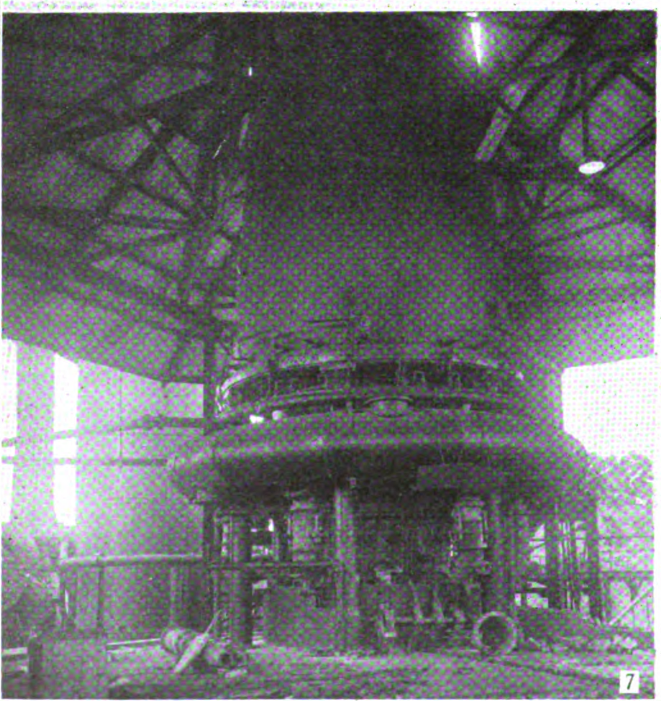
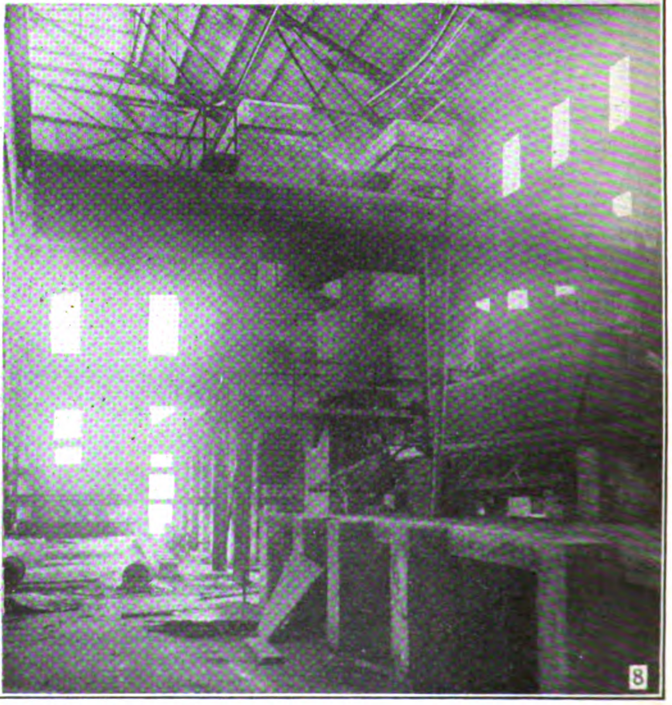

FIG. 5—Interior view of foundry, showing 48-in. cupola and core oven. **FIG. 6**—Interior view of machine shop, showing some of the machines. **FIG. 7**—View of blast furnace, showing iron runners and tapping hole, cinder runners and taping hole, tuyeres, bustle pipe, water cooling system, mud gun and operating floor of cast house. The sand for pig beds can be seen in foreground. **FIG. 8**—Inside view of still house, showing drying apparatus. In the foreground is shown one of four rotary drum dryers.

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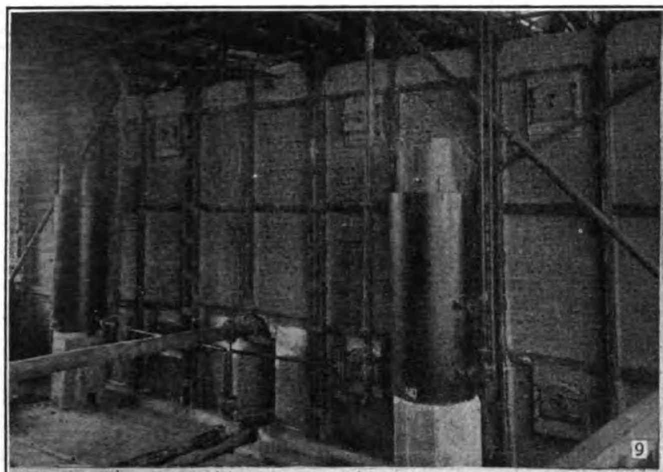

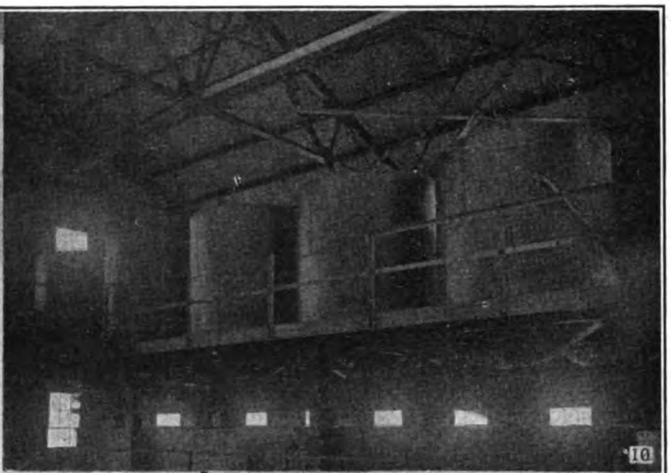

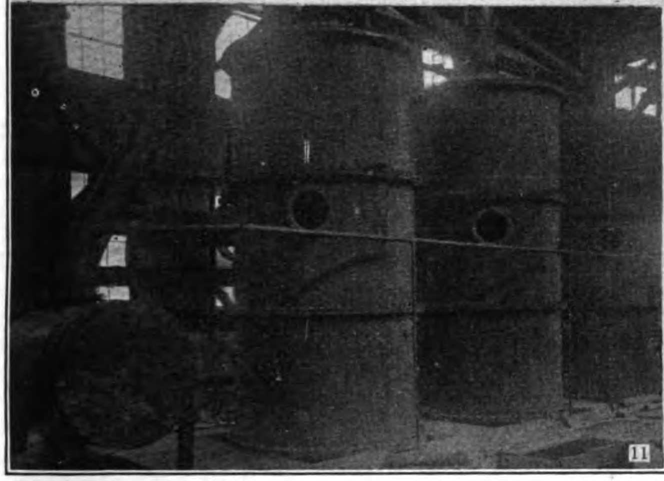

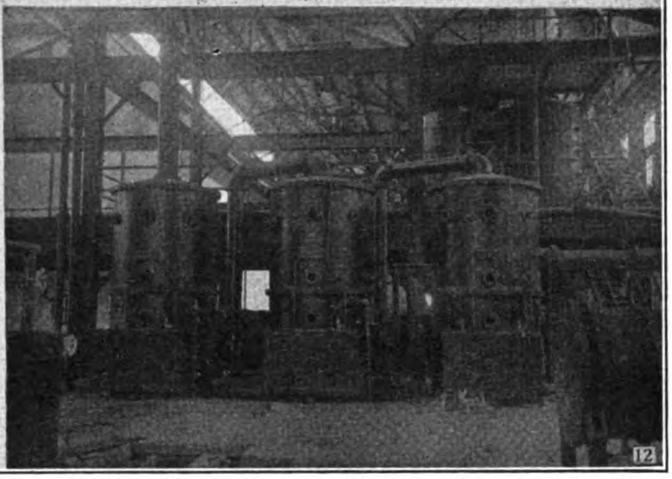

FIG. 9—View of brick setting for retorts for carbonizing the wood condensers, water, gas, and pyroligneous acid liquor piping, etc. FIG. 10—Interior view of still house, showing settling and settled liquor tanks. FIG. 11—Interior view of still house, showing evaporators. FIG. 12—View inside still house, showing evaporators for concentrating acetate liquor.

allowed to remain for 24 hours. It is then placed for the same period in secondary coolers, and from there it goes to the cooling shed, a large open building where after a further lapse of 24 hours it is removed to the blast furnace.

The machinery for the ore crushing plant was furnished by Messrs. Fraser and Chalmers to a design specially prepared by Dr. W. F. Smeeth, former Director of Geology to the Mysore State. It consists of two jaw crushers, each of which is driven by a 25-hp. slip ring motor.

The plant is located at the northern end of the blast furnace. The crushers are housed in a structure two-stories high, with a lean-to and cellar for the crushers and a pit about 20 ft. deep for the elevator. The building itself is of steel with asbestos siding and roofing.

The ore or flux is deposited through gate chutes at the bottom of bins into tip wagons, which conveys it to an 18-in. track to either crusher, and on to a grizzly, where all pieces under 2 in. pass through and fall in a chute and into a bucket elevator. The ore, after being crushed is elevated to the second story, and then into the wagons. Water and sludge from the washing machine go to a dewatering cone, where, the water overflows into the sewer and the sludge received in tip wagons and taken to the refuse dumps.

The blast furnace has a capacity of 60 tons per day. The total volume of the furnace is 3,000 cu. ft. which works out at 50 cu. ft. of volume for each ton of iron produced per day.

The furnace is lined with hearth and bosh quality fire-brick, which is of highly refractory character. This material is employed up to a point 12 ft. 4-5/16 in. above the bosh line, after which a harder and less refractory quality is used, up to the throat line, and from there upwards, bricks are employed to withstand abrasion.

Two Mesta Uniflow blowing engines capable of delivering 10,000 cu. ft. of air against a pressure of 10 lb. working against a back pressure of 10 lb., furnish the air for the furnace. One of these is in regular use, and the other is held as a spare. At the rate of 60 tons of iron per day, the maximum amount of air required should not exceed 6,000 cu. ft per minute; but provision was made for 10,000 cu. ft. units in order to meet the demand which would arise if the rate of production were increased to 100 tons per day. Three stoves 14 ft. diameter by 60 ft. in height with 6-in. checkers, each containing 9,000 ft. of heating surface, provide the heat for the blast. Allowance has been made for the addition of a fourth stove, should production be raised to 100 tons per day. These stoves are heated by the gas from the blast furnace, the gas thus absorbed being just one-third of that produced, the remaining two-thirds being employed for generating steam at the boilers.

(Concluded on page 274)

Cyanid Accumulation in the Blast Furnace*

Cyanid Accumulation Has Been Found Sufficient to Account in Vaporization for Over 30 Per Cent of the Coke Burned to Keep the Hearth Hot

By RICHARD FRANCHOT†

PART II

The fact of cyanid accumulation was first pointed out by Lowthian Bell. The fact of vaporization is patent in the clouds of fog or smoke seen whenever gas flows freely from the smelting zone, notably when gas is allowed to blow at the end of a cast. That vaporization absorbs heat need hardly be said. At two furnaces smelting Mesabi ores with Connellsville coke, the writer has found the fume collected from gas taken out at different points, from a few feet above the mantel down to the cinder notch, to contain from 20 to 80 per cent water-soluble potassium cyanid or its equivalent and widely varying percentage of carbon, silica, alumina, lime, and magnesia with small amounts of zinc, manganese and sulphur. Sometimes the fume carries substantial percentages of iron. The average of a large number of samples of fume obtained at the cinder notch (after casting) shows 58 per cent cyanid and 35 per cent of slag constituents. Measurements of the cyanid concentration of gases taken from the cinder notch have shown as much as 9 lb. KCN per 1,000 cu. ft., over 4 per cent by volume. The accordance of this observed cyanid concentration with the variation of the nitrogen-oxygen ratio of the tuyere gases as observed by Perrott and Kinney[8] has been pointed out by the writer.[9] We here have a basis of fact upon which to estimate the heat taken out of the hearth by vaporization. Per pound of carbon burned, producing 85 cu. ft. of gas, 0.76 lb. cyanid with 569 cal. vaporization heat accounts for 400 cal.; and assuming the same latent heat for the slag vapor, the 35 per cent of slag constituents in the fume may be taken to indicate an absorption of 240 cal. We now have this estimate of the appropriation of the hearth heat as developed by the air:

	Calories	Per cent
Decomposition of moisture.......	80	7
Water cooling and radiation......	200	16
Vaporization of cyanid...........	400	32
Vaporization of slag.............	240	20
Smelting work (difference).......	315	25
	1235	100

It may be pointed out that the indicated 8 per cent (25 of 31 per cent) specific efficiency with respect to useful smelting work at 1500 deg. C. allows, on a usual production of the order of 1.5 lb. pig per pound carbon burning with air, some 200 cal. per pound of pig iron. This would provide 98 cal. for the reduction of 2 per cent silicon, as represented by $SiO_2 + 2C = 2CO + Si - 137{,}680$ cal., or 4900 cal. per pound silicon; 20 cal. for adding the final 100 deg. heat, at 0.2 specific heat, to the liquid iron and 17 cal. at 0.33 specific heat to the slag; with 65 cal. for other work devolving upon the hearth. In the absence of observed facts on which to base a direct estimate of the average cooling effect of the iron and slag as they run through the combustion zone, the allowance of 200 cal. per pound pig iron may be taken for what it is worth. At least, it squares with the broad theory of the smelting process, which nowhere postulates a minimum temperature of 1500 deg. for any of the chemical work involved.

We can now say, on the basis of the above estimate of hearth-heat appropriation, that the burden is limited by the low efficiency of the hearth; about 8 per cent of the total heat developed appears to be usefully applied. The decomposition of moisture accounts for less than 2 per cent of the total heat, 5 per cent is lost by cooling, and 84 per cent is carried by the gas up the shaft, 68 per cent as sensible heat of CO and N_2, 16 per cent as latent vapor heat. The furnace appears to act to a remarkable extent as a reflux condenser, over half of the hearth heat, therefore half of the coke burning with air being primarily devoted to vaporization. It appears that the volatility of the materials is a large factor holding down the hearth temperature and raising that of the shaft. The formation of scabs on the furnace walls is facilitated by the condensation of the vapors rising from the hearth. In slag constituents alone, a production from air of 50,000 cu. ft. of gas per minute indicates 270 lb. per min. as the rate of vaporization, or about 175 tons per day. In such a furnace, making 550 tons of iron with a 50 per cent slag ratio, or 275 tons, this vaporization figure sheds an interesting light on the mechanism of slag formation and on that of lining preservation. A cyanid concentration of 9 lb. per 1,000 cu. ft. of hearth gases suggests a vaporization rate of 324 tons per day, the rate of input of alkalies in the charge (0.2 per cent K_2O) being the equivalent perhaps of 6 tons per day. and indicating 50 as a coefficient of accumulation and circulation. This carries rather seductive implications as to the nitrogen-fixing capacity of the blast furnace. For the present, however, we are chiefly concerned with the immense economic significance of cyanid accumulation, from the standpoint of the iron maker.

Cyanid accumulation alone seems to be sufficient explanation of how and why the furnace acts as gas producer. The burden seems to be definitely limited by the necessity of vaporizing accumulated cyanid to less than half that which, in the absence of cyanid accumulation, could (subject to secondary limiting factors) be charged with the coke. Expressed conversely, it appears that a definitive proportion of the coke is chargeable to cyanid vaporization. About 30 per cent of the 80 per cent or more of the coke that burns with air appears to be devoted to cyanid vaporization. The equivalent of about 70 per cent of the coke carbon now leaves the furnace as CO. Formation of CO with reversion of CO_2, caused by excess heat in the shaft, has been shown to involve an average of 25 per cent of the coke carbon leaving as CO. It now appears that, in the absence of cyanid and other conditions being unchanged, about 25 per cent of the total coke could be dispensed with in the hearth and with 30 per cent less hot gas going through the shaft, solution loss (12.5 per cent) would probably disappear and the present 70:30 ratio of CO and CO_2 would be changed to 20:40.5, or 32 per cent CO to 68 per cent CO_2. We may thus conclude that at least 37 per cent of the coke consumption, over 70 per cent of the gas production, is now primarily chargeable to cyanid accumulation.

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*Presented at the annual convention of the American Institute of Mining and Metallurgical Engineers, New York, February, 1926.

†Vice President, Ferro Chemicals, Inc., Washington, D. C.

It now remains but to test the hypothesis by its application in detail to actual operating results. This application involves only a simple transposition of the heat balance. It is usually formulated to give the heat developed and appropriated per unit of pig iron, making no distinction, on the one hand, between carbon oxidized to CO by air and that so oxidized otherwise nor between what should be classed as useful smelting work and what may properly be regarded as losses deductible from the fuel values on the other. It would seem desirable, in the interest of clarification, to distinguish between air oxygen and ore oxygen, the latter being, as Johnson[10] suggests, an asset to the smelting work rather than of the heat development. The fact that the air is a rather important factor in the heat development seems to be, at times, somewhat neglected. Manifestly the active agent developing and maintaining the furnace heat is the air burning coke in the hearth. Possibly this is the only positive heat development in the furnace. At any rate, it is certain that the coke gasified otherwise than by air is involved in heat-absorbing rather than heat-developing reactions. Clarity of view results from formulating the heat balance on the basis of the carbon burning with air, this being, moreover, in a given furnace a fairly constant quantity, the variation in coke consumption per ton of pig being essentially a variation of burden.[11]

As an example illustrative of present-day practice we may choose one of the fourteen furnaces listed by Royster, Joseph and Kinney[12] in their article, Heat Balance of Bureau of Mines Experimental Furnace. Of these fourteen large furnaces, No. 4 seems to be doing the best all around work, producing in a 17-ft. hearth, 90-ft. stack, 582 tons of bessemer iron (1.29 per cent silicon) without scrap, with 2070 lb. coke ratio carrying 1.20 per cent sulphur, 13 per cent ash, and 85.26 fixed carbon, the slag ratio being 1390 lb. (1.74 sulphur) blast heat 1025 deg. F., top heat 352 deg. F. Following are the significant data:

CO_2 ratio of top gas, per cent (12.9:25.2)	33.8
Coke carbon, lb. per pound pig iron	0.788
Slag ratio, lb. per pound pig iron	0.626
Stone ratio, lb. per pound pig iron	0.584
Stone carbon, lb. per pound pig iron	0.063
Fuel carbon, lb. per pound pig iron	0.748
Carbon in gases, lb. per pound pig iron	0.811
Ore oxygen in gases, lb. per pound pig iron	0.424
Carbon equivalent (¾), lb. per pound pig iron	0.318
Carbon equivalent of ore oxygen and stone CO_2, lb. per pound pig iron	0.381
Actual carbon as CO_2 in gases, lb. per pound pig iron	0.273
Solution loss, lb. per pound pig iron	0.108
Carbon burned by air, lb. per pound pig iron	0.640
Pig produced, lb. pig per pound carbon with air	1.56
Wind blown, cu. ft. (standard) per min	41,109
Solution loss, per cent of coke	13.7
Carbon in pig, per cent of coke	5.0
Burned by air, per cent of coke	81.3
Solution loss, per cent of carbon burning with air	**16.8**

In explanation of the method of deriving the carbon burned by air, Gruener's ideal is to have all the ore oxygen and limestone carbon leave as CO_2, in which event all the coke carbon less that going into the iron, 0.748 lb. C. would burn to CO with air and the ore oxygen (equivalent to 0.318 C.) would all be used in oxidizing CO to CO_2. With the stone CO_2 (0.063 lb. C.) there would then be, per pound pig iron, the equivalent of 0.381 lb. carbon as CO_2 in the gases. The actual carbon as CO_2 shown by the gas analysis however is only 0.273 lb. per pound pig iron. Hence, the difference, 0.108 lb. carbon, is gasified by CO_2 (or ore oxygen) to CO and this leaves 0.64 lb. carbon to burn with air. It may be noted that the solution loss is really a balance between the gross amount of carbon gasified by CO_2 and the carbon deposited from CO in the reversal of the gasifying reaction, $2\ CO = C + CO_2 + 38{,}880$ calories. This reaction, known to take place in the furnace, is overbalanced and thus often lost to view when the shaft is not choked with deposited carbon.

The weight of gases formed in the furnace per pound carbon burning with air is approximately:

6.7	lb. CO and N_2 from air
0.168	lb. carbon by solution loss
0.661	lb. oxygen from ore (0.424 × 1.56)
0.360	lb. CO_2 from stone (0.231 × 1.56)
7.889	lb. total gases

In addition there may be 0.5 lb. steam from moisture in the charge and water added.

The smelting work or cooling effect involved in the production of a pound of pig iron under the conditions existing in this furnace is estimated as follows:

	Calories
Heating 1 lb. metal	330
Heating 0.62 lb. slag at 550	341
Calcining 0.58 lb. stone at 451	261
Reduction 0.94 lb. iron at 1746	1641
Reduction 0.02 lb. silicon (manganese and phosporus) at 7000	140
	2713
CREDITS	
Formation of slag 0.62 × 80	49
Solution of carbon in iron	28
Oxidation of CO to CO_2 by ore oxygen (0.318 lb. C)	1803
	1880
Net heat absorbed per pound pig iron	833

The reduction of hematite by CO is an exothermic reaction and no heat is required for its maintenance. When taking place at relatively high temperatures, and in the presence of carbon, the CO_2 formed reverts to 2CO, absorbing heat. As has been shown, the latter action is secondary and it should properly be accounted separately. The same considerations apply to the reduction of silica, etc. The primary reaction is probably between molecules of SiO_2 and CO forming CO_2 and at the temperature required for this reduction, the CO_2 takes up carbon (which may be deposited higher up in the furnace). The oxygen involved in reduction comes from the ore and should, strictly regarded, be itemized separately rather than lumped with the air combustion as is usually done.

The balance sheet of the furnace, accounting for the total heat developed by the air blown in at the tuyeres follows:

HEAT DEVELOPMENT

	Calories
1 lb. carbon forming CO	2430
Blast heat 5.7 lb. air 1025 deg. F	780
1 lb. carbon preheated to 1500 deg	650
	3860

HEAT APPROPRIATION

Decomposition of blast moisture (assumed)	80
Preheating carbon	650
Smelting work 1.56 × 833	1299
Solution loss 0.168 × 3240	544
Top heat dry gases 7.89 lb., 352 deg. F	349
Top heat evaporated moisture 352 deg. F	304
Water cooling and radiation (difference)	634
	3860

It may noted that in the item of smelting work there is a credit of 2812 cal. for the oxidation by ore oxygen of 0.496 lb. carbon from CO to CO_2 (5670 cal. per pound carbon). Deducting from this 544 cal. for the gasification of 0.168 lb. carbon by equivalent CO_2 leaves 2268 cal. as the net heat of the secondary oxidation by ore oxygen. Obviously this involves no change from the balance that would be obtained by figuring that 32.8 per cent of the carbon burning to CO with air is oxidized to CO_2 by ore oxygen, giving 1860 cal. and that coke equal to 16.8 per cent of that burning with air is oxidized to CO by ore oxygen giving 408 cal., a total heat credit to ore oxygen of 2268 cal. Either of these methods of accounting is preferable to that generally used, which, applied here, would figure that 0.328 lb. carbon is burned to CO_2 with 2657 cal. (8100 cal. per pound) and 0.84 lb. carbon to CO with 2041 cal., a total heat development of 4692 cal. corresponding with the above primary development by the air of 2430 cal. with 2268 secondary, by aid of the ore. As above suggested, the present method seems to be more closely related to what actually goes on in the furnace.

This balance sheet exemplifies what was said when discussing solution loss, namely the simple fact that the heat developed by air in the hearth is greatly in excess relative to the purely heating work involved in the process. After charging off radiation and decomposition of blast moisture, the surplus heat amounts to 61 per cent of the heating work, including the preheating of carbon, 92 per cent of the smelting work proper, and 31 per cent of the total heat developed or 45 per cent above the heat actually absorbed in useful work and unavoidable losses. The surplus heat, 1197 cal. per pound carbon, is reflected in the solution loss and top heat including moisture evaporation. It may be surmised that, in the absence of solution loss and moisture in the charge, the excess heat would appear in a top heat of about 1,000 deg. F. as compared with the present 352 deg. As things are, nearly half of the surplus heat is devoted to making combustible gas out of CO_2 and coke. Not being able to add, say, 10 per cent to the burden and thus use a small part of the 92 per cent surplus heat in increasing production, and thereby lowering the coke ratio, the furnace must be content to let about a third of its CO_2 revert to gas and carry off 13 per cent of the coke on its way to the hearth. Without the surplus heat, that is, with about 30 per cent less coke burning with air there would still be an excess of CO over the present 50 per cent used in reduction and it does not seem unreasonable to suppose that this excess CO would then be forced to generate in carbon deposition sufficient heat to dry the charge. So doing, CO drops half its carbon, the other half going to CO_2 and developing 1620 cal. per pound carbon as CO. It thus appears that 20 per cent of the present CO from the hearth possesses latent heat sufficient to dry the usual ore and coke. The practice of pumping water into the top to keep it cool and hold down dust would have to be discontinued. However, 30 per cent slower driving, without cutting off production, would help solve the flue-dust problem. Net deposition of carbon replacing the present gasification would help out the coke supply. Incidentally, such deposited carbon brings no sulphur into the furnace. It would pay to use a cheap fuel for heating the blast, if the furnace could be made to convert more of its fuel energy into pig iron instead of gas.

On any furnace, a properly drawn heat balance gives mathematical expression to the major premise of operation. In the present example, this premise is: In developing the available heat required in the hearth the amount of reducing gas produced is double that which can be oxidized to CO_2 by the ore, 31 per cent of the total heat developed being in excess, by 45 per cent over the heat absorbed in useful smelting work and radiation. The resultant rise of temperature in the stack is reflected in a reversion to CO of 16.8 per cent of the coke carbon with a gasification of 16.8 per cent additional coke. This effect involves the delivering by the furnace, as CO, of over 70 per cent of the fuel carbon charged. A minor premise comprises the observed fact of cyanid accumulation as measured by the cyanid concentration of the hearth gases and the variation of the nitrogen-oxygen ratio of these gases. Cyanid accumulation so measured has been found sufficient to account in vaporization for over 30 per cent of the coke burned to keep the hearth hot. Therefore it may be concluded, as a matter of inexorable logic (mathematics) that cyanid accumulation limits the ratio, iron production to coke consumption to that which can absorb only 51 per cent of the coke energy, the other 49 per cent (70 per cent of 70 per cent) leaving the furnace in the form of combustible gas. In short, cyanid accumulation makes the blast furnace about half a gas producer. The obvious corollary is: Take cyanid out of the blast furnace and thereby improve fuel economy.

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"Safety Spats" for Tin Plate Workers

"Safety spats" for tin plate workers have been devised by Peter F. Haberstick, safety director for the Wheeling Steel Corporation, with a view to eliminating the cutting of the Achilles tendon on the heels of hot mill workers, and severing arteries on their insteps. The "safety spats," as they have been christened, are of leather of the same design as the spats worn with low shoes. Passed through them are what resemble paper clips or staples, and down the rear are two piano wires.

When hot packs of plate come sliding across the floor, wearers of these devices need have no fear of serious injury such as results now in case the red-hot steel plates come in contact with the heel or instep.

Commutation Troubles in D. C. Machinery

The Cause and Elimination of 20 Different Kinds of Sparking Are Explained in Detail by the Author in This and Two Preceding Articles

By EARL B. STAVELY*

THE preceding article of this series included a discussion of the general theory of commutation and of the requirements which must be met if satisfactory commutation conditions are to be obtained. Certain of these requirements will be restated briefly here as an introduction to the present article.

Part III of a series of articles dealing with causes of sparking and their symptoms, including a useful tabulation of the symptoms associated with each of the more common causes of sparking. Following articles will deal with the selection and maintenance of brushes, and the maintenance and repair of commutators.

Commutation Principles.

(1) The current in an armature coil must be reversed during the period when its commutator bars pass a brush. Sparking will occur if this current reversal is seriously delayed or is not completed during this period.

(2) Due to this reversal of current a voltage of self induction is developed in the coil which opposes, and therefore delays, the reversal of the current. This voltage varies directly with the load.

(3) The voltage of self induction may be neutralized, either in whole or in part, by providing means whereby a second voltage, in the opposite direction and of proper value, will be developed in the coil during the commutation period. In commutating pole machines this voltage is developed by the motion of the coils through the magnetic field produced by the commutating pole. In non-commutating pole machines the brushes are shifted so that they commutate the coils while they are moving through the fringe of the magnetic field of the main pole of the "new" polarity.

(4) During the commutation period an armature coil is short circuited by the brush. An excessive local circulating current will be produced in the coils as they undergo commutation if a sufficiently high voltage is effective in causing current flow in this local path. The resistance of this path is quite low, since the path consists of an armature coil and the brush and contacts between brush and commutator, hence a comparatively high local current will be produced by a voltage of only a few volts. This local current is in the same direction as the load current over one-half the brush contact and in the opposite direction over the other half, hence this local current will increase the current density at a portion of the brush contact and decrease the density at the other portion. Sparking will occur if the density at the one portion of the contact exceeds the maximum safe operating limit.

Incorrect Brush Setting on Commutating Pole Machines.

The brushes of commutating pole machines must be set on the "neutral axis" if they are to commutate the armature coils properly, as these coils move through the magnetic field of the commutating poles. A comparatively slight deviation from the correct setting will produce such undesirable results that the correct setting is carefully determined at the factory and indicated by suitable marks on the machine.

If the brushes of a commutating pole motor are not correctly set the machine may be very unstable as to speed, the speed suddenly increasing, then after a moment decreasing, then increasing again, and so on. Similar unstable voltage conditions occur in generators.

Incorrect brush setting also leads to serious sparking since the coils are not commutated while in the proper position with respect to the field from the commutating pole. Under this condition the voltage of self induction is not neutralized as described in the preceding section and sparking results. This sparking is of a bluish-white color, produces a snapping noise in severe cases, and causes serious burning and pitting of a portion of the brush face.

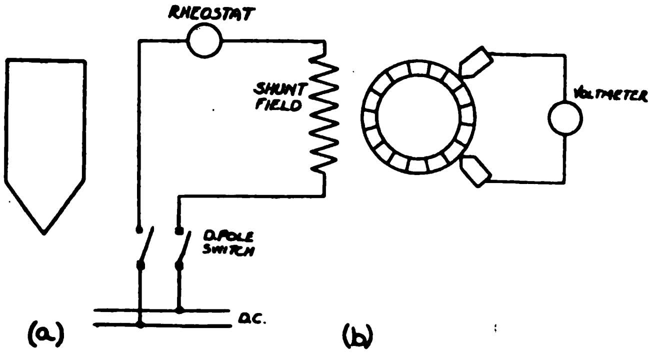

FIG. 1—Test for checking brush setting. (a) Shape of special test brushes. (b) Connection diagram.

Incorrect Brush Angle.

The brushes may not be in the proper position on the commutator even though the brush studs and brush rigging are set exactly on the marks placed on the machine at the factory. This condition is most frequently caused by a change in the tilt of the brush holders, hence in the brush angle with respect to the commutator face, when machines are repaired or overhauled, or when brush holders are replaced.

Checking Brush Setting by Test.

If difficulty is experienced in determining the cause of sparking in a commutating pole machine, it will be well to check the brush setting by test. Various types of tests have been devised for this purpose, each having certain advantages and disadvantages. One of the most simple methods calls for the following procedure while the machine is at rest: Disconnect the armature circuit from the line. Connect the field circuit to the line, with a rheostat in series to limit the current to normal value, and with a switch for opening and closing this circuit. In two brush holders of adjacent studs place specially prepared brushes which have been beveled as shown in Fig. 1-a, and connect these test brushes to a low scale voltmeter. Carefully note whether the voltmeter needle is momentarily deflected when the field circuit is closed or opened. If a deflection of the voltmeter is found the brushes are not properly set and the brush rigging should be shifted until a setting is found at which no voltmeter deflection can be obtained when the field circuit is closed or opened. The test brushes then indicate the "neutral" points on the commutator.

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*Associate Professor of Electrical Engineering, The Pennsylvania State College.

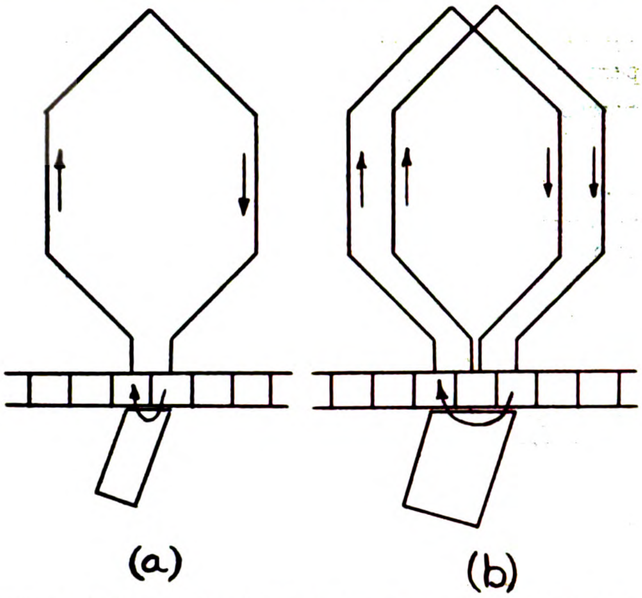

FIG. 2—Effect of brush thickness on number of coils short circuited by a brush. Path of local circulating currents indicated by arrows.

The regular brushes should then be set so that the centers of the brush contacts with the commutator fall exactly on the points previously occupied by the tips of the special test brushes. For this reason care should be taken, in preparing the test brushes, to bevel the brushes so that the edge is in the center. Fig. 1-b gives a schematic diagram of connections for this test.

Defective Commutating Pole Coils.

Short circuits between turns of the commutating pole coils is a common cause of sparking in machines which are frequently subjected to severe sustained overloads. The resulting overheating of machines thus operated causes a deterioration of the insulation on the coils if these are made of cotton covered wire. Short circuits between turns then develop, especially if the machine is subject to vibration or is operated in wet and dirty surroundings.

The strength of the magnetic field developed by the commutating pole coil depends upon the number of turns on the coil and the current flowing in the coil. Short circuits between turns produce a result equivalent to a reduction in the number of turns, hence reduce the strength of the field produced by a given coil current. If the field strength is thus reduced, the voltage induced by this field in the armature coils undergoing commutation will not be sufficient to neutralize the voltage of self induction developed in these coils and sparking may occur for reasons stated previously.

It is well, therefore, to test the commutating pole coils for short circuits when a machine is overhauled or repaired, or when difficulty is experienced in determining the cause of sparking.

A reversed commutating pole coil, or a reversed commutating pole circuit, will cause very serious sparking of a vicious bluish-white character. In this case the voltage induced in the armature coils by the commutating pole field is in the same direction as the voltage of self induction, hence the reversal of current in the armature coils is opposed rather than aided by the commutating poles.

The commutating pole circuit and the armature are connected together properly and checked at the factory, and this connection should not be disturbed if possibility of trouble is to be avoided.

Thick Brushes.

As noted previously, sparking may be caused by excessive local currents circulating in the armature coils short circuited by the brushes. The use of brushes which are too thick is one cause of such local currents.

As shown in Fig. 2-a, a brush with an arc of contact equal to the width of one commutator bar can short circuit only one coil at a time, hence the voltage effective in causing local currents is the voltage of one coil. With a thicker brush, as shown in Fig. 2-b, the brush short circuits two coils, hence the voltage of two coils becomes effective in producing local currents as indicated by the arrows in this figure. With a still thicker brush three coils will be shorted and the voltage of three coils will be effective in causing local currents.

The thickness of the brush and the size of the brush holder are determined and fixed when a machine is designed. The purchaser cannot, therefore, use a thicker brush without replacing the holders. He can, however, change the tilt of the brush holders on the studs and thus increase the arc of brush contact as will be noted by comparing Fig. 3-a and Fig. 3-b. Increasing the arc of contact in this way is equivalent to increasing the thickness of the brush and should be avoided since in many machines a comparatively small change in brush holder tilt will cause the brush to short circuit too many armature coils and sparking will occur due to local circulating currents.

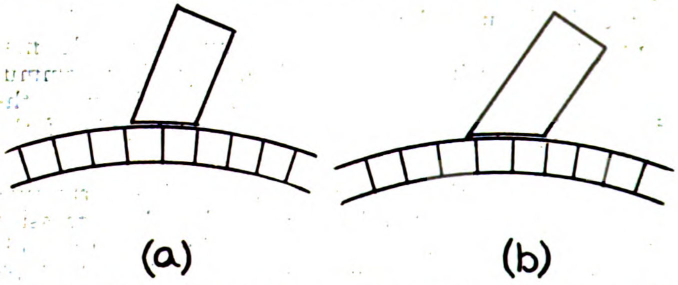

FIG. 3—Effect of brush tilt on number of bars in contact with a brush. Increasing the brush tilt may increase the number of coils short circuited by the brush—the effects being similar to those resulting from an increase in brush thickness as shown in Fig. 2.

Alignment of Brush Studs.

Another condition under which excessive local currents may occur is shown in Fig. 4. Here the brush stud is not parallel with the shaft, thus causing the group of brushes to short circuit considerably more armature coils than are short circuited when the stud is parallel with the shaft. Since the holders are electrically connected by the stud the effect in this case is the same as that which would result from the use of a wide brush set at an equal angle with the axis of the commutator. Poor alignment of a stud may, therefore, lead to serious sparking at the brushes of that stud.

The alignment of a stud may be checked by turning the armature until the edge of a commutator bar is directly under the tip of one brush. If the stud is parallel with the shaft the tips of all other brushes on that stud will be directly above the edge of the commutator bar. An incorrect indication will be given here if the brush holders do not have the same tilt, hence it is well to check this point before checking the alignment of the stud as described.

Copper Coating on Brush Face.

A coating of copper is sometimes found on a part or on the whole of the brush face. This proves quite troublesome since a metallic coating of this kind greatly reduces the resistance of the contact between brush and commutator and may lead to serious unbalance in current distribution between brushes on the same stud, a condition which causes sparking and burning of the brushes as described previously.

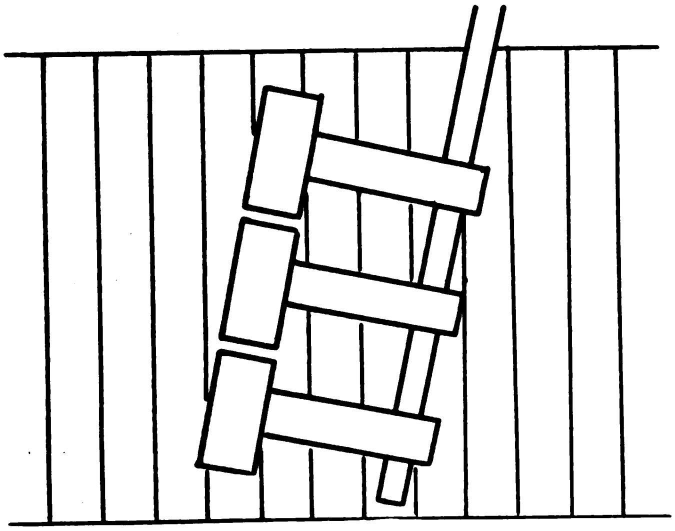

FIG. 4—Poor alignment of brush stud. Showing, in an exaggerated manner, how this increases the number of coils short circuited by the brushes of a stud.

When current flows from a brush to the commutator there is a tendency for minute particles of the carbon to be burned away and conducted across the gap by the current and deposited on the face of the commutator. When current flows from the commutator to a brush the tendency is for the copper to be burned away and deposited on the face of the brush. Fortunately, however, this effect becomes appreciable under ordinary conditions only in case the current density at the contact is quite high.

A copper coating over the entire brush face may be thus formed at the brushes where the current flows from commutator to brush if a machine is operated continuously under overload and with a correspondingly high current density at the brush contacts.

In cases where excessive local circulating currents exist in the armature coils short circuited by the brushes, the brushes are sometimes found to have a coating of copper over about half their face while the remainder of the face is clean. This results from the fact that, as shown in Fig. 2-a, the local circulating current adds to the load current at one-half the brush face while the current at the other half of the face is the difference between local and load currents. Under poor commutation conditions the local current may be greater than the load current, hence the current density at a portion of the brush contact may be considerably greater than the current carrying capacity of the contact. Sparking will occur under such conditions and in many cases the formation of deposits of copper on about half of the brush face becomes quite marked.

Other Causes of Sparking.

Sparking which occurs when a machine is operated under overload results chiefly from the fact that the current density at the brush contacts exceeds the maximum density under which the brushes can be operated without heating and burning at the contact. The effects here are cumulative since the burning causes pitting of the brush face, this increases the resistance of the contact, and this in turn causes greater heating and further burning, and so on.

A poor foundation, or poor mounting of the machine, may lead to considerable vibration, and this may make it impossible to make good contact between brushes and commutator without operating the machine with an unusually high brush pressure. This is to be avoided if possible since it leads to increased losses and heating at the commutator.

In machines with badly worn bearings the air gap between poles and armature is less at the lower parts of the machine than at the upper parts. Under such conditions the voltage between brush studs may become badly unbalanced and cause circulating currents between brush studs by way of the connections between studs of the same polarity. Sparking may then result since this circulating current increases the current density at the brush contacts.

The same result occurs in case the armature winding is unbalanced, that is, in case there is not always the same number of coils in series between adjacent studs regardless of the position of the armature with respect to the brushes. Such unbalance may be caused by the temporary "cutting out" of defective armature coils.

Defective field coils, defective brush holders, broken brush springs, and many other defects in a d.c machine will tend to cause sparking.

Summary of Symptoms.

This article, and the two preceding articles, explained how sparking is caused and pointed out the symptoms usually associated with each cause. The accompanying tabulation gives a summary of the general symptoms which characterize each of the more common causes of sparking.

The table notes the symptoms associated with each individual cause of trouble if that cause only is involved. In many cases two or more of these causes of sparking exist simultaneously, and under these conditions the symptoms usually differ somewhat from those associated with each of the individual causes. For example, sparking may be due in part to brush chatter and in part to the presence of dirt. The first cause tends to produce sparks of a bluish-white color, while the second tends to cause sparks of a reddish-brown color. As a result, the sparks may be of a yellowish-white, or reddish-yellow color. Similar variations in the brush and commutator symptoms will be found under certain conditions of operation. In order to limit the tabulation to a reasonable space, no attempt has been made to include symptoms associated with different combinations of two or more causes of sparking. A comparison of existing symptoms with those noted in the table should make it possible to determine which of two or three possible causes of trouble might well be investigated. In other cases the table may indicate at once the cause.

This tabulation should, therefore, be of considerable assistance in the analysis of sparking troubles, especially since most handbooks and instruction books give only tabulations of causes and remedies, leaving to the man in the field the most difficult phase of the problem—that of determining the cause.

As noted in the first article of this series, it is believed that commutation problems can best be solved by making a careful analysis of the symptoms shown by the machine under consideration.

Iron and Steel Tester Developed

A new device for testing iron and steel has been designed and developed in the past few years and will soon be put on the market by the Steel Penetrometer Company, 1910 Highland Avenue, Detroit. It is an electrical apparatus which makes use of the varying electrical apparatus of alternating magnetic flux penetration of soft, hard or heat-treated steel or iron. It is stated that the test consumes but a second of time, that it is reliable, and readily lends itself to the testing of large numbers of pieces, it being capable of making 100 per cent inspection tests rather than the usual laboratory sample test. The test, of course, is non-destructive of the material tested.

An important feature announced is the depth of gage, enabling the operator to tell at a glance at what depth the test is being conduced. It is stated that die blocks can be inspected by this method, giving the degree of hardness at varying depths, with the hardness readings readily comparable with Brinell, scleroscope and Rockwell hardness numbers.

CHARACTERISTIC SYMPTOMS OF COMMON CAUSES OF SPARKING IN D. C. MACHINES

SPARKS	COMMUTATOR	BRUSHES	MISCELLANEOUS	CAUSE
Brownish-red	Dirty black	Trailing tips burned		Dirt on commutator face
Brownish-red ring fire	Dirty black	Trailing tips burned		Very dirty commutator
Yellowish ring fire	Adjacent bars "blued" and their mica pitted	Trailing tips burned	Local overheating of armature coils	Short circuits between bars Defective mica between bars
Yellowish-red	Greasy black	Greasy face		Oil or grease; soft brushes
Yellowish-white at portion of brush	Blackened	Half of face burned, rest not burned		Wrong brush setting; thick brushes; wrong brush tilt
Yellowish-white at end brushes of stud	Blackened, sometimes in rings	Face of sparking brushes burned, others not		Brush studs not parallel with shaft
Yellowish-white at some brushes of same stud	Blackened, sometimes in rings	Face of sparking brushes burned, others not		Unequal division of current between brushes of same stud
Yellowish-white	Blackened	Copper deposit on entire face of brushes on alternate studs		Excessive current density at brush contacts; continuous excessive overload
Yellowish-white at portion of brush	Blackened	Copper deposit on half of brush face		Excessive local current in coils short circuited by brushes
Yellowish-white at part of some brushes	Blackened, sometimes in rings	Portion of face burned, rest appears "new"		Poor fit of brushes on commutator Poor fit of brushes in holders
Bluish-white	Blackened	Entire face burned	Brushes chatter	Vibration; rough commutator; low brush pressure; short brushes
Bluish-white	Blackened	Entire face burned	Brush chatter at high speed, screech at low speed	Dry commutator; hard brushes
Bluish-white	Bars blackened, edges of mica blackened	Entire face burned	Slight brush chatter	High mica
Bluish-white	Local blackening	Leading tips chipped, face burned	Brush chatter at high speed, "pound" at low speed	High bar; loose bar; low bars
Bluish-white	Local blackening	Entire face burned	Brush chatter, "note" varying with speed	Eccentric commutator; unbalanced armature; poor belt joint
Bluish-white	Grooved	Slightly burned	Sparking at intervals	Severe overload at intervals
Severe bluish-white	Badly blackened	Face badly burned		Brushes sticking in holders Broken brush spring
Severe bluish-white	Badly blackened	Face burned, edges badly burned	Sparking produces slight snapping noise	Wrong brush setting; short circuits in commutator pole coils
Bluish-white at certain studs	Blackened	Brushes at sparking studs burned, others not		Unequal brush spacing; unequal air gaps due to worn bearings
Vicious bluish-white	Severe local burning	Badly burned and pitted	Sparking produces sharp snapping noise	Open circuit in armature winding Reversed commutating pole connection

Review of Rolling Mill Literature

This Review Covers Both American and Foreign Rolling Mill Literature Published During 1925, and Is One of the Most Comprehensive Ever Compiled

By RICHARD RIMBACH*

ABBREVIATIONS USED IN THE FOLLOWING BIBLIOGRAPHY

B. F. & S. P.—Blast Furnace and Steel Plant
Ber. Walzw. Aussch.—Bericht des Walzwerksausschuss des Verein deutscher Eisenhuttenleute
B. of S. T. P.—United States Bureau of Standards, Technical Paper
Compt. rend.—Comptes rendus hebdomadaires des seances des l'Academie de Sciences
Deut. Gesells. Metalk.—Deutsche Gesellschaft fur Metallkunde
El. Rev.—Electrical Review
El. Jour.—The Electric Journal
Eng.—The Engineer
Engg.—Engineering
E. T. Z.—Elektrotecknische Zeitschrift
F. S. H. .T—Forging-Stamping-Heat Treating
Foundry Tr. Jl.—The Foundry Trade Journal
Fond. Mod.—La Fonderie Moderne
Giess. Ztg.—Giesserei Zeitung
G. E. Rev.—General Electric Review
Industria—Industria
Iron Age—Iron Age
Ir. Tr.Rev.—Iron Trade Review
Ir. St. Eng.—Iron and Steel Engineer
Ir. Coal Tr. Rev.—The Iron and Coal Trades Review
Jl. Ir. & St. Inst.—Journal of the Iron and Steel Institute
Jl. Phys. Chem.—Journal of Physical Chemistry
Jernk. Ann.—Jern-Kontorets Annaler
Mech. Eng.—Mechanical Engineering
Mach.—Machinery
Machy.—Machinery (London)
Metal. Ind. (N. Y.)—Metal Industry (New York)
Masch. B.—Maschinenbau
Proc. Cleve. Inst. Engrs.—Proceedings of the Cleveland Institution of Engineers
Proc. Inst. Mech. Engrs.—Proceedings of the Institution of Mechanical Engineers
Power House—Power House
Proc. Roy. Soc.—Proceedings of the Royal Society, London
Rev. Met.—Revue de Metallurgie
Rev. Gen. Elec.—Revue Generale Electric
Ry. Rev.—The Railway Review
S. u. E.—Stahl und Eisen
Staffordshire—Staffordshire Iron and Coal Trades Review
Siemens Z.—Siemens-Zeitschrift
Trans. A.I.M.M.E.—Transactions of the American Institute of Mining and Metallurgical Engineers
Yearbook A.I.&S.I.—Yearbook of the American Iron and Steel Institute
Zeits. V. d. I.—Zeitschrift des Vereines deutscher Ingenieure
Z. Metallk.—Zeitschift fur Metallkunde
Z. Phys.—Zeitschrift fur Physik
Z. Berg.-Hutten Salinenwesen—Zeitschrift fur das Berg-, Hutten-und Salinenwesen
Z. angew. Math. Mech.—Zeitschift fur angewandte Mathematik und Mechanik

JANUARY

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The Manufacture of Chilled Iron Rolls	R. A. Cole	Proc. Inst. Mech. Engrs.	Jan. 1925	93-98
Pioneer Pipe Producer Re-enters Market (Clayton Work & Co., Chicago)	Gilbert Lacher	Iron Age	1-22-25	270-272
Recherches experimentales sur le laminage du fer a chaud. (Experimental Investigations of the Hot Rolling of Iron)	N. Metz	Rev. Met.	Jan. 1925 Feb. 1925	1-20 66-87
Steelmakers Seek Refinements in Rolling		Ir. Tr. Rev.	1-1-25	24
Rolling Mills Completed or Building During 1924	J. D. Knox	Ir. Tr. Rev.	1-1-25	63
Main Roll Drives in the United States and Canada		Ir. St. Eng.	Jan. 1925	29-54
Bibliography of Rolling Mill Papers Presented Befor A. I. & S. E. E.		Ir. St. Eng.	Jan. 1925	55-56
The Continuous Rolling Mill	L. D. Whitehead	Staffordshire Ir. Coal Tr. Rev. Ir. Coal Tr. Rev.	1-31-25 2-6-25 2-13-25	 211-213 252-255
Ueber das Vareilen beim Walzen	D. Dresden	Z. angew Math. Mech.	Jan. 1925	78-79

FEBRUARY

Title	Author	Periodical	Date	Pages
Das Breiten beim Walzen	W. Tafel & H. Sedlaczek	S. u. E.	2-5-25	190-193
Translation of Above	Richard Rimbach	Ir. Tr. Rev.	3-12-25	693-695
Spring Steel from Cold Roll Strip Mills (Wallace Barnes Co.)		Iron Age	2-5-25	399-402
Die Entwicklung der Electrischen Walzwerkantriebe	R. Rohde	E. T. Z.	2-12-25 2-19-25 2-26-25	217-223 261-267 319-320
Rolling Mill Electric Operation; Compilation of Main Drives in the United States and Canada by Class of Mill and Type of Connection		Iron Age	2-12-15	488-489
Verformen und Rekristallisiren; theoretische betrachtungen Kaltverarbeitung der Metalle	F. Körber	S. u. E.	2-12-25	217-223
Gear Drive for Sheet Rolling Mills		Engg.	2-13-25	206

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*Metallurgist, Swissvale, Pa.

Title	Author	Periodical	Date	Pages
Gear Drive for Sheet Rolling Mills.................		Ir. Coal Tr. Rev.	2-13-25	269
Le Groups Kraemer dans son Application a la commande d'un Train de Laminairs. (The Kraemer Group and Its Application in Control of Rolling Mill Trains)	J. Marquin	Rev. Gen. Elec.	2-14-25	261-264
Distribution of Rolled Steel by States.............		Iron Age	2-19-25	539-550
Dispelling Drudgery in the Hot Mill...............	J. D Knox	Ir. Tr. Rev.	2-19-25	503-506, 543
Beitrag zur Theorie des Walzvorganges............	T. V. Karman	Z. angew Math. Mech.	Feb. 1925	139-141
Ueber langsame stationare Stromungen in plastischen Massen mit Rucksicht auf die Vorgange beim Walzen, Pressen und Ziehen von Metallen........	H. Hencky	Z. angew Math. Mech.	Feb. 1925	115-124
MARCH				
New Double Drive for a Reversing Two-high Rolling Mill		Ir. Coal Tr. Rev.	3-6-25	385-386
Tinplate Doubling Machine		Ir. Coal Tr. Rev.	3-6-25	401
Vergleichende Zug-, Druck-und Walzversuche......		S. u. E.	3-12-25	373
Calculating Spread in Rolling. (Translated from Stahl und Eisen 2-5-25)..........................	W. Tafel & H. Sedlaczek	Ir. Tr. Rev.	3-12-25	693-695
Die Fliessgrenze des Eisens.......................		S. u. E.	3-19-25	434
Rolling Rails—History	G. T. Raidabaugh	B. F. & S. P.	Mar. 1925	110
			Apr. 1925	167
Properties of Matter Under High Pressure........	P. W. Bridgman	Mech. Eng.	Mar. 1925	161-169
Factors Involved in the Selection of Direct-Connected and Geared Main Roll Drives....................	E. A. Hurme	Ir. St. Eng.	Mar. 1925	111 & 150-151
Discussion: Gear Drives in Steel Mills............	W. E. Sykes	Ir. St. Eng.	Mar. 1925	146-148
APRIL				
Electrification of a 10-Inch Rolling Mill...........		Ir. Coal Tr. Rev.	4-3-25	550
Chain-Driven Cold Rolls...........................		Ir. Coal Tr. Rev.	4-10-25	580
Remodeled and Electrified Rod Mill...............	S. N. Roberts	Ir. St. Eng.	Apr. 1925	153-159
The Mill-Type Magnetic-Time Control System......	J. D. Wright	G. E. Rev.	Apr. 1925	243-247
Tubing Made from Strip Stock; How Flat Stock Is Rolled and Sweated into Double-Wall Tubing....	C. O. Herb	Mach.	Apr. 1925	602-605
MAY				
Drahtwalzwerk mit Schleppwalzen..................		S. u. E.	5-7-25	723
Influenza del corroyage nel senso delle fibre trasversali alla laminazione delle lamiere................	P. d'Angelo	Industria	5-15-25	232-234
Zur Berechnung von Schienenkalibrierungen........	H. Cramer	S. u. E.	5-21-25	799-802
Ueber das Wesen des plastischen Verformung......	H. Hencky	Zeits V. d. I.	5-16-25	695-696
New Plant Rolling Charcoal Iron. (Reading Iron Company			9-26-25	1253-1254
		Iron Age	5-21-25	1486-1488
Replaces Forge Plant with Charcoal Bloomary......	E. C. Kreutzberg	Ir. Tr. Rev.	5-21-25	1319-1321
Blooming Mills and Blooming Mill Practice........	W. H. Bailey	Yearbook AI&SI	5-22-25	26-83
		Iron Age	7-2-25	6-7
			7-30-25	271-320
		Ir. Tr. Rev.	5-28-25	1390-1391
			6-4-25	1454-1455
			7-23-25	192-193
Progress in British Rolling Mill Practice...........	T. W. Hand	Jl. Ir. & St. Int.	May 1925	43-112
		Eng.	Vol. 139 No. 3620	539
		Engg.	12-5-25	778-781
		Ir. Coal Tr. Rev.	12-12-25	811-814
			5-8-25	729-741
Application of Synchronous Motors to Continuous Mills	F. O. Schnure	Ir. St. Eng.	May 1925	226-227
Inspection Trip—Brier Hill Sheet Mill of Youngstown Sheet & Tube Co..........................	E. L. McElhinney, E. F. Rhodes and S. Kneass	Ir. St. Eng.	May 1925	222-226
Factors Involved in the Selection of Direct Connected and Geared Main Roll Drives....................	E. A. Hurme	Ir. St. Eng.	May 1925	189-222
Ueber die Herstellung von Eisen-und Stahl draht und kaltgwalztem Bandeisen und Bandstahl in den Vereinigten Statten	U. Mattsson	Jernk Ann	May 1925	229-275
Repairs to Rolling Mill Engine Shaft..............	E. R. Norris	B. F. & S. P.	May 1925	193
JUNE				
Analyzing Blooming Mill Operation................	W. H. Bailey	Ir. Tr. Rev.	6-4-25	1454-1455
Experiments in the Manufacture of Chilled Iron Rolls	A. Allison	Foundry Tr. Jl.	6-4-25	481-483
			7-9-25	27-30

Title	Author	Periodical	Date	Pages
Looping Blooming Mill; Unusual Type, Over 20 Years Old		Iron Age	6-11-25	1707
Valuable Facts to Know About Rolled Steel Wheels	G. S. Richardson	Ry. Rev.	6-13-25	1070-1074
Operating Plate, Bar and Rod Mills	H. A. Hatfield	Power House	6-20-25	26-28
Surface Cracks in Rolling Steel	H. A. Hibbard	Iron Age	6-25-25	1837, 1879-1880
			7-9-25	77, 124-125
Ueber die Entwicklung von Eigenspannungen beim Kaltwalzen von Messing	G. Masing	Z. Metallk	June 1925	183-186
Ueber Deformations-und Rekristallisationsstrukturen von Metallen	R. Glocker	Z. Phys.	June 1925	386-410
JULY				
Blooming Mill for Homestead Works of Carnegie Steel Co.		Iron Age	7-9-25	81
Ueber Hartguss	P. Goereus & H. Jungbluth	S. u. E.	7-9-25	1110-1117
Eigenspannungen in Walzstaben unter besonderer Beucksichtigung der Schienen	P. Berdenheuer	S. u. E.	7-9-25	1098-1101
(Internal Stresses in Rolled Steel with Special Reference to Rails). Translation of above		Ir. Coal Tr. Rev.	7-24-25	141
Electrically-Driven Hoop and Strip and Rod Mills at Newport Mills at Middlesbrough		Ir. Coal Tr. Rev.	7-10-25	49-50
34-Inch Universal Plate Mill at the Clydesdale Steel Works		Engg.	7-10-25	36-38
			7-24-25	93
			8-7-25	156-159
			8-21-25	222-224
Reclaiming Wobblers; Several Applications of Arc Welding for Repairs in Steel Mills	R. L. Scollard	Iron Age	7-16-25	152-153
Electrical Driving in a Constructional Steel Works		Ir. Coal Tr. Rev.	7-17-25	98
8-Inch Merchant Bar Mill. (Donner Steel Co.)		Iron Age	7-23-25	201-204
Builds Large Roll Grinder		Iron Age	7-30-25	279-280
		Machy. (Lond.)	8-6-25	589-591
Toll Turning Lathe of 26-Inch Centers		Machy. (Lond.)	7-30-25	570-571
Die elektrisch betriehenen Umkehrstrassen der Firma Les Petite-Fils de Francois de Wendel & Cie	Seibert & Stork	Siemens Z.	July 1925	268-273
Leistungsberechnung des Walzvorganges	L. Weiss	Z. Metallk	July 1925	229-232
Why Hard Chilled Rolls Become Rough	H. Harris	B. F. & S. P.	July 1925	287
Einiges aus der Praxis der Hartguss-giesserei	Friese	Giess Ztg.	7-15-25	397-399
Giant Uniflow Engine for Steel Mill Drive		Power	7-28-25	122-125
AUGUST				
Electric Billet Shear		Engg.	8-7-25	163-164
Skelp Mill at the Works of Alfred Hickman—Branch of Stewarts & Lloyds, Ltd		Ir. Coal Tr. Rev.	8-14-25	243-245, 257-260
Zur Frage der bildsamen Formandexung	H. Preussler	S. u. E.	8-20-25	1422-1428
Effect of Rolling Condition on Carbon Steel	C. H. S. Tuphalme	Ir. Coal Tr. Rev.	8-21-25	284
History and Development of the Bridgeport Brass Company	A. D. Guion	Metal Ind. (H. T.)	Aug. 1925	311-321
Spalling of Sheet and Tin Plate Rolls	H. Harris	F. S. H. T.	Aug. 1925	275-276
		B. F. & S. P.	Aug. 1925	334-335
Electrical Drives for Rolling Mills	H. C. Uhl	Ir. St. Eng.	Aug. 1925	322-327
Observations on Rolling Mill Drives in Continental Europe	O. Needham	Ir. St. Eng.	Aug. 1925	327-331
Foreign Steel Mill Practice	F. L. Estep	Ir. St. Eng.	Aug. 1925	319-322
Orientation of Steel Rod Mills	G. H. Cole	Ir. St. Eng.	Aug. 1925	334-336
SEPTEMBER				
Krafte und Materialfluss bei der bildsamen Formanderung	E. Siebel	S. u. E.	9-10-25	1563-1566
Novel Motor Drive in Brass Mill	G. L. Lacher	Iron Age	9-17-25	733-737
The Theory and Practice of Rolling Steel	W. Tafel	Ir. Tr. Rev.	9-17-25	677-679
Translated from the German by Richard Rimbach			9-24-25	739-741
			10-1-25	824-825
			10-15-25	964-966
			10-22-25	1033-1036
			11-5-25	11-43-1146
			11-19-25	1277-1280
			12-3-25	1404-1406, 1434
			12-17-25	1530-1533
Herstellung Nahthloser Rohre	M. Doderlein	S. u. E.	9-24-25	1632-1639
Advantages of Adjustable Speed Drives for Rolling Mills	W. B. Shirk	Elec. Jour.	Sept. 1925	414-417

Title	Author	Periodical	Date	Pages
OCTOBER				
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Making Seamless Tubes by Improved Process	F. F. Ross	Ir. Tr. Rev.	10-29-25	1079-1083, 1091
New Sheet Bar and Hot Strip Mills	F. L. Prentiss	Iron Age	10-30-25	1141-1146
Fabrication des cylindres de Laminairs en forte. (Manufacture of Cast Iron Rolls)		Fond. Mod.	Oct. 1925	213-214
Plasticity	E. C. Bingham	Jl. Phys. Chem.	Oct. 1925	1201-1204
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Scraping Defects from Hot Steel		Iron Age	11-19-25	1375-1377
Die Verwendung von siliziertem und unsiliziertem Stahl zur Herstellung von nahtlosen Röhren nach dem Schragwalz-und Pilgerschrettverfahren	C. Wolff	S. u. E.	11-26-25	1958-1961
Die grundlegenden Vorgange der bildsamen Verformung	H. Meyer & F. Nehl	S. u. E.	11-26-25	1961-1972
DECEMBER				
Reason for Breakage of Mill Rolls	Walter Dawson	Iron Age	12-10-25	1587-1588
Rolls First Steel Bars on New 14-Inch Mill. (Ford Motor Co.)		Ir. Tr. Rev.	12-10-25	1460-1461
Large Powered Rolling Mill Drivers		Engg.	12-19-25	842
American Blooming Mill Practice	W. H. Bailey	Iron Age	12-24-25	1739-1745
The Removal of Scale During Rolling	F. L. Estep	F. S. H. T. B. F. & S. P.	Dec. 1925 Dec. 1925	425-426 476-477
Die Herstellung von Schraubengewinden durch Warmwalzen	G. Martin	Masch B.	Dec. 1925	576-578
Application of Theory of Elasticity to Plastic Deformations	E. Hungerer & J. Koenigsberger	Z. Phys.	Dec. 1925	903-913
Electric Rolling Mills	D. W. Blakeslee	Ir. St. Eng.	Dec. 1925	508-512
Choice of Electric Drive for Reversing Mills	L. A. Umansky	Ir. St. Eng.	Dec. 1925	479-500
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Effect of Hot-Rolling Conditions on the Physical Properties of a Carbon Steel	J. R. Freeman, Jr., & A. T. Derry	B. of S. T. P. No. 267	1925	547-566
Flow in Low-Carbon Steel at Various Temperatures	H. J. French & W. A. Tucker	B. of S. T. P. No. 296	1925	619-640
Plastic Deformation of Iron and the Formation of Neuman Lines	W. Rosenhain & J. McMinn	Proc. Roy. Soc.	1925	231-239
Zur Frage Der Bildsamen Formanderung	A. Preussler	Ber. Walzw. Aussch.	1925	No. 36
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Reviewed in		S. u. E.	9-10-25	1563-1566
Vergleichende Untersuchungen Auf Kraftbedarf und Walzleistung an Blockstrassen		Ber. Walzw. Aussch.	1925	No. 40
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Zur Mechanik der Bildsamen Formanderungen	A. Nadai	Ber. Walzw. Aussch.	1925	No. 56
The Effect of Reheating on Cold Rolled Steels	Delbart	Comp. Rend.	1925	934-937
The Manufacture of Chilled Castings	Vallische	Founry Tr. Jl.	1925	456-457
The Manufacture of Flat Wire		Eng.	1925	193-196
Scratch and Brinell Hardness of Severely Cold Rolled Metals	M. F. Fogler & E. J. Quinn	Trans. A.I.M.M.E.	1925	
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BOOKS				
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General Principles of the Beneficiation of Iron Ores*

By T. T. READ†

PART II

IT was pointed out in Part I of this paper‡ that at present the almost universal method of making iron from ore is to reduce the oxide with carbon in a blast furnace, slag off the other impurities, and fuse the resultant iron so it can be drawn out in the liquid state. The iron thus made has 3 to 5 per cent of carbon in it, and for every purpose except cast iron, has to go through another process to remove the carbon. It is not essential that iron smelting shall be done this way, it is merely the cheapest and most efficient method that has yet been devised. It was not the original way of iron production, for in the earliest processes the iron oxide was merely reduced to iron without fusion and, being nearly free from carbon, could be wrought by heating and hammering. The product was not, of course, modern wrought iron, which is carbon-free iron made from pig iron by a puddling process perfected in 1785. In the puddling process the pig iron is melted and gradually oxidized to eliminate carbon; the pure iron gradually freezes as it loses its carbon, and is worked into a ball and rolled. The sonims, which have been converted into slag, are gradually squeezed out in the rolling and the final result is a high-grade product. In the earlier process the sonims remained, except insofar as they were mechanically removed by the repeated hammering to which the iron was subjected. With pure iron ore and pure carbon (charcoal was universally used) a fairly high-grade product could be made, but not from ore which contained much impurities. It is generally said that the old process was wasteful of labor and fuel, but the principal reasons why it was abandoned was because it was not adapted to large-scale production and it did not effectively eliminate sonims.

Principles of Reduction of Iron from Iron Oxides.

A clear understanding of the principles involved in the reduction of iron from iron oxides can best be obtained by first considering§ the oxygen pressures of iron oxides and of carbon monoxide (CO) and of carbon dioxide (CO_2). Silver oxide, when heated to a temperature between 200 and 300 deg. C., gives an oxygen pressure greater than that of the atmosphere, so it may be reduced to the metallic form by simply heating it in air. The iron oxides, however, give very low oxygen pressures at all temperatures below their fusion points. They cannot be reduced by heating in air, but must be heated in an atmosphere in which very low oxygen pressures are created by the presence of "reducing agents." The oxides Fe_2O_3, Fe_3O_4, and FeO have decreasing oxygen pressures in the order given, but as the higher oxides apparently pass through the FeO stage during reduction, the reduction of FeO to Fe governs the whole process. CO_2 has a higher oxygen pressure than FeO and will oxidize it; CO has a lower oxygen pressure than FeO and will reduce it according to the reaction

$$FeO + CO \rightleftarrows Fe + CO_2$$

When CO and CO_2 are both present their combined oxygen pressure may be equal to that of FeO at various temperatures, and plotting these values gives the equilibrium diagram which appears as Fig. 1 in the report just cited, from which the foregoing statement has been taken.

If we put this concept in more general language, it may be said that when iron oxides are heated in the presence of air or CO_2 nothing happens. If the heating is done in the presence of CO_2 and CO, there is for each temperature a ratio between CO and CO_2 below which nothing happens and above which the CO reduces the iron oxides to Fe; the speed of the reaction depending on the excess of CO above the equilibrium ratio, as well as on the temperature. The work of reduction is done by the CO. It is evident this must be so, because the solid particles inside a blast furnace are bathed in a flood of rapidly moving gas, and there would be no practicable way for an atom of carbon to make contact with a molecule of iron oxide except through first being converted into CO.

In blast-furnace smelting the oxygen entering through the tuyeres burns to carbon monoxide:

$$2\,C + O_2 = 2\,CO.$$

The CO immediately passes upward while the heat thus generated fuses the iron and the slag, raises them to the temperature at which they escape from the furnace, raises the gases (chiefly CO and N_2) to the temperature prevailing in that zone, and some heat is lost in a variety of ways. Only the small part of the heat produced in the hearth that is used in heating up the gases aids in the reduction of the iron oxide.

Higher up in the furnace, and at a much lower temperature, the CO reduces the iron oxide of the ore to iron. As the CO_2 thus produced is able to oxide Fe to FeO, 100 per cent excess of CO over equilibrium is required to keep the reaction progressing. Even on this basis 64.3 units of carbon should suffice to reduce 100 units of Fe, but in ordinary blast-furnace practice we find that 100 units or more of carbon are required to produce 100 units of pig iron. In other words, in the practical operation of the blast furnace, three times as many units of carbon have to be used as are theoretically necessary for the elimination of the oxygen in the iron ore. More than two-thirds of the cost of making pig iron out of ore is the cost of the fuel required for the operation. The total cost of the pig iron, of course, includes the cost of the ore delivered at the furnace, which is over half the total for basic and Bessemer pig; the cost of making pig iron from the ore being about 48 per cent of the total cost of the pig iron, which is made up of the cost of the iron-bearing material, plus the cost of making iron from it. One-half or more of the cost of the iron-bearing material is due to transportation and about one-third of the cost of the fuel is due to transportation, so that the largest item in the cost of pig iron is transportation. But the largest item in the cost of making pig iron from iron-bearing material is the cost of fuel. As stated above, fuel amounts to between 65 and 70 per cent of the iron-making cost; fluxes and labor amount to about 7 per cent each, and the remainder is made up of a variety of smaller items.

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*Published with approval of the Director, U. S. Bureau of Mines.

†Formerly Safety Service Director, U. S. Bureau of Mines, and Superintendent of North-Central Experiment Station, Minneapolis, Minn.; now assistant secretary American Institute of Mining and Metallurgical Engineers.

‡This journal, March, 1926.

§Williams, C. E., Barrett, E. P., and Larsen, B. M., "The Production of Sponge Iron." Reports of Investigations, Serial No. 2656, Bureau of Mines, November, 1924, 21 pp.

Function of Carbon Monoxide in Blast Furnace.

It was stated above that blast-furnace smelting by the usual method is the most efficient and economical method yet devised. This may appear inconsistent with the statement that three times the theoretical amount of carbon is required for reduction. There is no inconsistency, however, because for the reduction of the iron oxide, CO is required, and in the blast furnace the available heat of the reaction in making CO from carbon is utilized to fuse the metal and slag, thus killing two birds with one stone. "Direct reduction" processes are essentially attempts to produce CO for reduction purposes without raising the temperature high enough to fuse the metal produced. Obviously such a separation of reduction and melting operations can not be more economical than the combined process unless by separating them it is possible to accomplish the reduction with a smaller excess of CO than is practicable in the blast-furnace process; or conversely, when the melting requires the burning of more carbon to CO than is required to yield the amount required for reduction. The melting of iron in a cupola for foundry purposes only requires about one-tenth as much carbon per ton of molten metal as is burned in the blast furnace, and this might be taken to indicate that more heat is being produced in the zone of the tuyeres than can be profitably utilized. This is not true, however. The metal and slag do not escape from the furnace at any higher temperature than is necessary for proper working, so there is little saving to be made in that regard except by decreasing the slag volume and thereby its total heat. The remainder of the sensible heat is utilized in the upper zones, and only the radiation from the tall stack can be charged up as unnecessary loss.

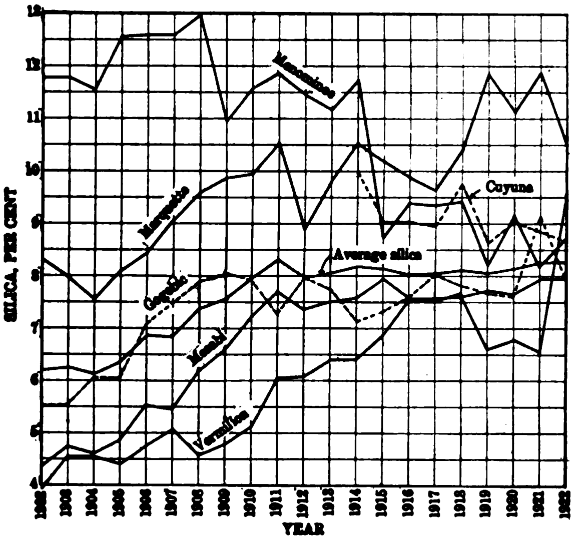

FIG. 1—Average silica content of total tonnage of Lake Superior iron ore. (Prepared by Lake Superior Iron Ore Association.)

About 30 per cent of the calorific value of the top gases is needed to pre-heat the blast, and the other 70 per cent is available for power generation. Much progress has already been made in the utilization of this heat, and there is further promise for the future. The present blast-furnace process therefore is at least as economical of fuel as any other process, the cost of fluxes is kept at a minimum by the use of as pure ores as can be obtained, and the large scale of operations reduces labor and other costs to a very small amount.

What Beneficiation of Ores Really Means.

However, in considering the possible use of lower grade ores for iron-making, it is not sufficient merely to consider the application of beneficiation methods to ores by which they may be raised to approximately the present grade of purity and then smelted as is done at the present time. Blast-furnace smelting is made up of three simultaneous operations, elimination of oxygen, fusing of the iron, and fluxing and fusion of the solid impurities in the ore. Under the present set of conditions it is most economical to do these simultaneously; under a different set of conditions it may be more economical to separate them.

As a concrete example of what is meant, suppose it eventually becomes necessary to utilize ore which is low in iron and high in alumina: By the present method this would involve the use of a large amount of fluxes which would not only increase the cost of fluxes, but also the cost of fuel for fusion, and also every other item in the iron-making cost, because the number of tons of pig iron the furnace could produce in a day would be decreased. The most obvious procedure would be to try to eliminate the alumina from the ore. Another method, and one that has often been proposed, is first to eliminate the oxygen from the iron oxide in the ore, then separate the iron from the alumina, etc., and finally fuse it. This is the basis of all the so-called direct process, of which a number have been investigated, without much success as yet, because the combined costs of the separate operations under most conditions exceeds the cost of the combined operation. It is evident that as the cost of fuel is the principal item in the combined operation, the most promising line of attack is one that suggests the possibility of reducing the fuel cost, if at the same time the resultant iron can be kept reasonably free from sonims and low enough in carbon so it does not have to be put through a carbon-eliminating (steel-making) process, the savings thus made may lead to a final production cost which will bring the process within the range of commercial practicability.

It seems unnecessary to attempt to review here what has been done on the direct production of steel from ore, and on the metallizing of iron oxide without fusion. The results are encouraging, but do not indicate that blast-furnace smelting, in the ordinary way, is likely to be supplanted except under special conditions, at any time in the near future. It is for this reason that this analysis of the general principles

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of the beneficiation of low-grade ores has been written largely from the viewpoint of blast-furnace smelting.

Elimination of Silica from Iron Ore.

Silica, like water, is always present in iron ores, but plays quite a different role. Water is easily and completely eliminated early in the course of the descent of the ore down the furnace, but silica can only be eliminated in the blast furnace through fluxing it and allowing it to escape in the form of slag. Not all the silica is slagged, however, for the high temperature and strong reducing action prevailing at the tuyeres is able to reduce some of the silica of the coke ash (and possibly of the slag) to silicon. How much is thus reduced depends upon a variety of factors, but chiefly the temperature; if the temperature is low the resultant iron will contain only about 0.5 per cent of silicon, while the iron from a hot furnace may contain as much as 4 to 5 per cent silicon. This reduction of silica to silicon is not always a loss, for the successful conduct of the acid-Bessemer process requires the presence of about 1 per cent silicon, but in the acid open-hearth, the slag contains about 46 per cent bases ($FeO + MnO$) and hence high silicon means increased metal loss. Except in the case of Bessemer pig iron, the presence of silicon in iron which is to be used for steel-making is not desirable, but rather an unavoidable consequence of maintaining the temperature requisite for securing a proper elimination of sulphur in the slag. As the amount of silicon in the pig iron seldom exceeds the amount originally present in the coke ash, both of these variables will, for simplicity, be disregarded and the silica in the ore discussed as though it were all disposed of by slagging it. This will not involve any serious error and will be much simpler.

Function of Limestone in Blast Furnace.

It will be assumed, therefore, that the silica in the ore is eliminated in the blast furnace by causing it to combine with lime and other bases, forming a fusible slag that may be drawn off in the liquid state. For this purpose 1½ to 2 units of CaO must be provided for every unit of SiO_2 that is present. Some iron ores, notably those of Alabama, in the United States, and of the Cleveland district in England contain notable amounts of CaO, but on the average the ore mixture is so deficient in CaO that it must be added in considerable amounts. As a matter of necessity lime has to be added in the form of limestone, $CaCO_3$ or about 1.8 units of limestone must be put in the furnace to provide 1 unit of CaO. The expedient has been tried of burning the $CaCO_3$ to CaO before putting it in the furnace, but there is no profit in this because there is enough CO_2 present at the top of the blast furnace to convert the CaO back to $CaCO_3$. Furthermore, a natural limestone seldom contains as much as 90 per cent $CaCO_3$ or its equivalent in magnesium carbonate, although it must be remembered in this connection that 1 unit of MgO is the chemical equivalent of 1.4 units CaO because of the difference in the atomic weights. For our purposes it is sufficient to say that the presence of 1 unit of silica in the ore involves the introducing of 3 units of limestone into the furnace charge to flux the silica. The cost of fluxes not only amounts to about one-seventh of the average total cost of the iron-making operation, but also involves the use of additional fuel for melting the slag and cuts down the output of the furnace by displacing an equivalent amount of ore that could otherwise be put into the furnace; in other words, one unit of silica in the ore displaces 4 units of Fe_2O_3 in the furnace mixture. For this reason it is regarded as a particularly objectionable impurity of ores. If the silica content of the ore mixture being smelted in Northern blast furnaces is under 6 per cent it is low, if it is over 10 per cent it is high. This rather narrow range of silica content is obtained by mixing ores that are high in silica with ores that are low in silica before putting them in the furnace. Generally speaking, a high silica ore is only tolerated because it is low in phosphorus, has some other good quality, or is needed to mix with low-silica material to give sufficient slag volume. The serious effect of silica content on the cost of pig iron made from the ore is more clearly brought out by the following hypothetical case, which has been more fully discussed elsewhere by the writer and others.*

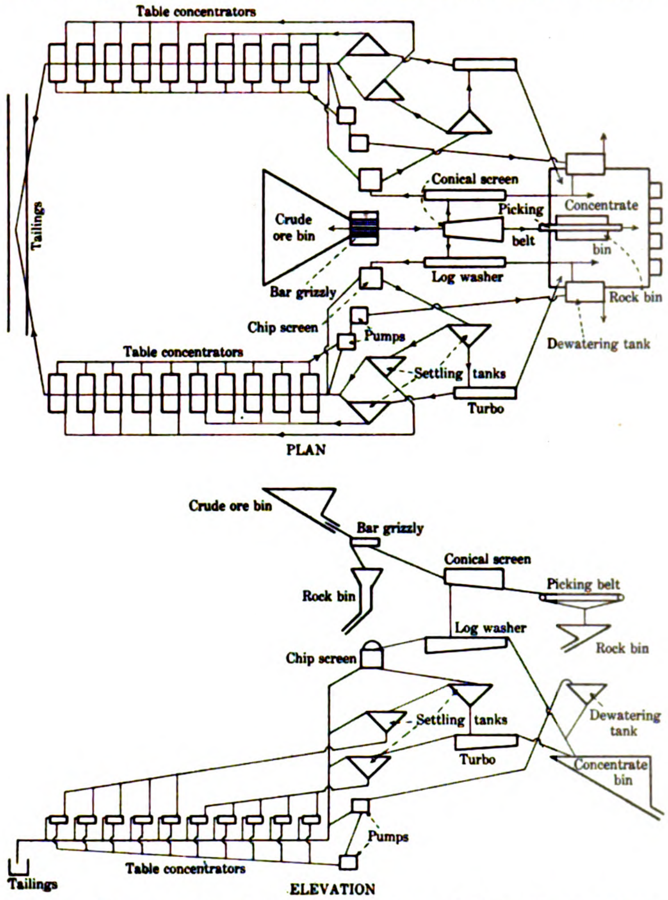

FIG. 2—Flow-sheet of Coleraine plant, Oliver Iron Mining Company. (After Sebenius.)

Effect of Silica in Ore on Cost of Pig Iron.

Assume that basic pig iron is being made from an ore which contains 51.3 per cent iron (natural) and 8 per cent silica; the slag, calculated to a basis of lime, alumina, and silica, being as follows: ($CaO + MgO$) 50 per cent; Al_2O_3, 15 per cent; and SiO_2, 35 per cent. Assume that the fuel consumption is 2,100 lb. of coke per ton of pig produced, and the cost of the pig iron produced is $20.56. Assume now that an ore is used which contains 49 per cent iron and 12 per cent SiO_2, everything else being the same—that is, 4 per cent Fe_2O_3 has been displaced by 4 per cent SiO_2. Then, using the analysis described in detail in the report cited below, the cost per ton of pig iron would be increased to $21.84 through the increase of fuel, flux, and lessened output. The only way to compensate for this increased cost is to cut it off the value of the ore delivered at the furnace, and if the ore went up to 16 per cent and down to 45.7 per cent iron, naturally the price which could be paid for the iron ore at the furnace and still make pig iron at the same cost as from 51.6 per cent iron 8 per cent silica ore would be less than the transportation cost between the Lake Superior region and Northern furnaces.

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*Read, T. T., Joseph, T. L., and Royster, P. H., "Effect of Silica in Iron Ore on cost of Pig-Iron Production." Reports of Investigations, Serial No. 2560, Bureau of Mines, 1924, 10 pp.

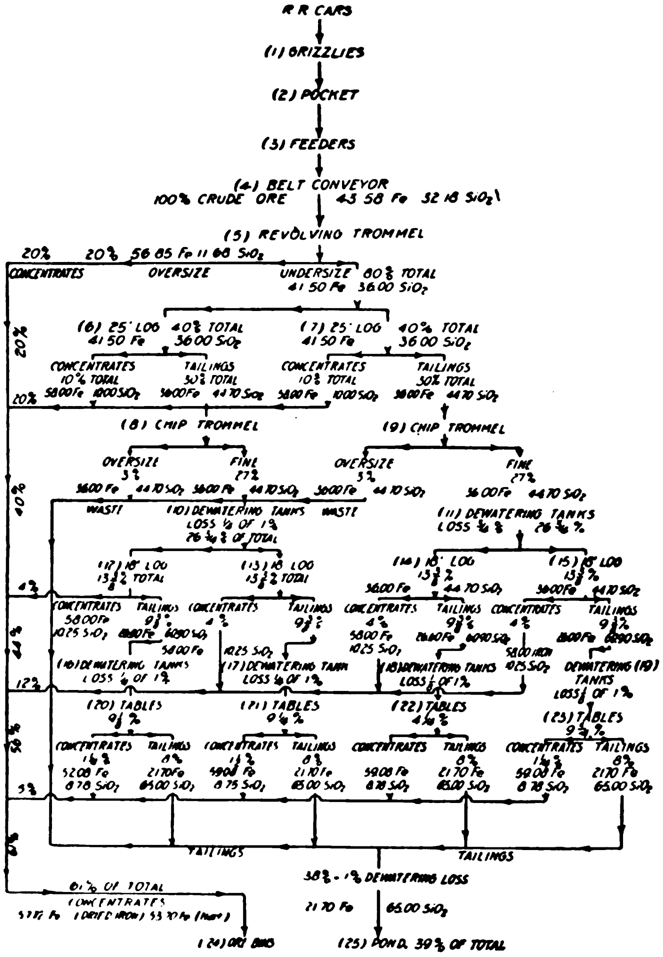

FIG. 3—Flow-sheet of one-unit iron-ore washing plant, Western Mesabi Range, showing approximate percentages and analyses. (After Kennedy in Eng. and Min. Jour.)

As a matter of fact, not a little iron ore containing over 10 per cent silica is shipped from the Lake Superior district and sold, under a penalty for its silica content, for use in furnaces where the material being smelted is so high in iron that not enough slag would otherwise be produced to insure satisfactory desulphurization.

Ratio of Coke and Slag to Iron Produced.

It may be noted here that the operating records of 23 Northern blast furnaces show that per ton of pig iron produced they consume 2,087 lb. of coke and produce 1,100 lb. of slag. This corresponds to an iron content of 32.8 per cent in the total dry solids charged to the blast furnace. An increase in the silica content of the ore cuts down the iron content of the dry solids charged not only by the lessened iron content of the ore but by the increase in flux and coke as well, and once the point is reached at which the furnace mixture gives enough slag to give satisfactory desulphurization with the coke used, any further increase in the amount of silica in the raw materials adds to the cost of the pig iron without producing any advantage.

It may be of interest to note here that the operating records of six Southern blast furnaces show that 2,552 lb. of coke is consumed and 2,445 lb. of slag is produced per ton of pig iron made. This corresponds to only 24.4 per cent of iron in the total dry solids charged to the furnace. The transportation cost on raw materials for Southern blast furnaces are so much lower than for Northern furnaces that the former are able to compete under the handicap of having to make iron out of materials of such a composition that, with two furnaces of equal cubic capacity the Southern furnace only contains three-quarters as much iron as the Northern furnace and, if it drove with the same speed, could therefore only make three-quarters as much pig iron per day. The actual average daily pig iron output of the six Southern furnaces is 85 per cent of the output of the 23 Northern furnaces.

Silica Content of Lake Superior Ores.

Fig. 1 (prepared by the Lake Superior Iron Ore Association) shows the average silica content (based on each season's shipments) of the ore shipped in the period 1902-1922 from the different districts of the Lake Superior region. Data for the preparation of such a chart are not available for the other ore producing districts of the country. One feature of the chart is immediately evident. In 1902, when the total shipments amounted to 27,500,000 tons, the range in silica was from 4 per cent for the Vermilion district to 12 per cent for the Menominee district. In 1916, when shipments amounted to 66,500,000 tons, the range of silica content was from 7½ per cent for the Vermilion district to 10 per cent for the Marquette district. The reason for the convergence of the silica curves is evident; as the silica content of the ores from the ranges, which produce low-silica ore increases, the amount of high-silica ore which can be mixed with them and make a satisfactory mixture decreases.

Examples of Removal of Silica from Ore by Washing.

Silica in iron ores does not create any difficulty in the iron-making process other than increasing its cost, in fact the production of a sufficient amount of slag is essential to the smooth working of the furnace. But, as pointed out above, its effect in increasing the cost of the resultant iron is so marked that it is the most important impurity removed by the usual beneficiation processes. Such processes frequently remove other impurities as well, and the most typical case of the removal of silica from iron ore before shipment is the washing process applied to the sandy ores of the Mesabi district, Minnesota. The first of these plants built was the Coleraine (also known as the Trout Lake) concentrating plant of the Oliver Iron Mining Company, which was completed in 1910. As this has been described* in detail by J. U. Sebenius, chief mining engineer for the Oliver company so only the essential features will be referred to here.

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*Proceedings Lake Superior Mining Institute, vol. 18, 1913, pp. 155-186.

At the western end of the Mesabi range, from Hibbing southwest to Grand Rapids, a distance of about 40 miles, about two-thirds of the tonnage of iron ore that has been developed is of too high silica content to be shipped as merchantable, but the silica content can be reduced to a workable amount by a single washing process because it exists in the form of fine sand particles that are separate from the iron-ore particles, and therefore require no crushing to free them.

The equipment used for this purpose is shown in Fig. 2, a flow-sheet of the Coleraine plant. The whole mill consists of five such units. The maximum capacity is 900 tons of crude ore per unit per hour, and the average 400 tons per hour. It is usually operated on two 10-hour shifts in weather when the temperature is above freezing. The largest tonnage washed in one season of six months exceeded 4,000,000 tons of crude ore. As there is no crushing the results vary widely, according to the variations in the ore, as it comes from the pit. The following figures are taken from the paper by Mr. Sebenius, already cited:

Product	Per cent of Total Concentrate
Belt	3 to 35
Logs	60 to 85
Turbos	2.5 to 10
Tables	1.5 to 6.5

The published descriptions do not give the ratio of concentrate to crude ore, but the concentrate probably amounts to between 60 and 70 per cent of the total product.

Between 1910 and 1923 nearly 30 plants of similar type were constructed on the Mesabi range. Some of these consisted of two units, many of 1 unit, and some were half-unit size. Fig. 3 is a flow-sheet from a paper by F. A. Kennedy,* "Iron Ore Concentration on the Western Mesabi Range." It shows a typical one-unit plant and gives the approximate distribution of sizes and iron content. It will be seen that from one ton of crude ore containing 43½ per cent Fe is obtained 0.61 ton of concentrate containing 53.7 per cent Fe, corresponding to a recovery of 75 per cent of the iron present. Mr. Kennedy estimated in 1919 that the working cost should not exceed 10 cents per ton of

Quarry (Crude ore:) met. iron 27%
silica 50%—Phos. .07
Cars—Capacity 24 tons each
Pocket—8 000 tons
Apron Conveyor—8′ wide
48″ x 72″ Jaw Crusher—Capacity 450 tons per hr.
Product 12″
36″ x 54″ Jaw Crusher 450 tons per hour
Product 6″
4—20″ Gyratories 100 tons per hour
each. — Product
1.5″
42″ Conveyor 400 tons per hour
55% full
Equalizing Storage Pile —25,000 tons
2—30″ Conveyors
Magnetic part to (Screens 2″) Non-magnetic Tails
cobbers to rolls (Screens 1.25″) to Rock Bin
and back to screens (Screens .25″)
(Screens 6 Mesh)
Final Product
(Amounting to two-third of original weight of which
50% is—150 Mesh)
Stock Pile—Capacity 70,000 tons
18″ Conveyor
Demagnetizer
6′ x 21′-8″ Door Classifier (-6 + 48)
4′6″ x 14′8″ Rake Type Duplex Wet Cobber (Product: Tails
& Concentrates)
Demagnetizer
2—8′ x 22″ Hardinge Ball Mills
4—8′ x 21′8″ Duplex Dorr Classifiers
Centrifugal Pump

Demagnetizer
6′ x36′—18″ diam. Bowl Type Door Classifier (-48 + 100)
1-Duplex Wet Cobber (Product: Tails &
Concentrates)
Demagnetizer
1—8′ x 22″ Hardinge Ball Mill
2—8′x32′—9′ diam. Bowl Type Dorr Classifiers
Separator Feed (-100)
5 Davis Magnetic Rake Washers
(Products: Tails & Concentrates)
Perfect separation showing
99.8% recovery.
5 Davis Magnetic Spiral Washers
2—5′ x 20′ Dorr Thickeners
Collecting Box
2—6′ x 10′ Oliver Filters (1 is spare) Product: Filter Cake &
Filtrate. Cake contain
10.5% moisture.
Filter Cake
Cake Cutter
18′ Conveyor
Hopper
Feeder
(Cake Cutter)
Sinter Machine Dwight Lloyd) (300
tons per 24 hours)
Sinter Cake (Met. iron 64%—Silica
9%—Phos. .027)
Toothed Rolls (Crushed to 4″ size)
Cooling Tower
Cars

FIG. 4—Flow-sheet of Mesabi Iron Company's plant at Babbitt, Minn., Eastern Mesabi Range. (After Handbook of Lake Superior Mining Institute, 1923.)

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*Engineering and Mining Journal, vol. 107, 1919, pp. 683-688.

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crude ore. The recovery is somewhat low compared with the average of wet concentration plants treating other kinds of ore, but this is an almost inevitable consequence of a single cheap process. As the crude ore could not possibly be used for furnace treatment it may be argued that the tailing loss is not a loss in the ordinary sense of the word, because the untreated material is of no value.

Examples of Beneficiation of Ore by Magnetic Separation.

As a contrast to this simple, cheap process, applicable to the ores of the western end of the Mesabi Range, the process that is applied to the ore of the extreme eastern end of the Mesabi Range may be cited. In contrast to the western ore that at the eastern end is extremely dense and hard. The iron-bearing formation has there been closely approached by the margin of a huge laccolithic intrusion of gabbro, and the iron mineral is largely in the form of magnetite in grains 1/100 inch in diameter or larger, though some of the magnetite grains are as small as 1/599 inch diameter. The minerals in the ore are magnetite, quartz, and amphibole, with subordinate amounts of carbonate and hematite. The workable beds contain between 20 and 30 per cent iron in the magnetic form, and are therefore amenable to magnetic concentrate providing the magnetite grains can be freed from adhering silica.

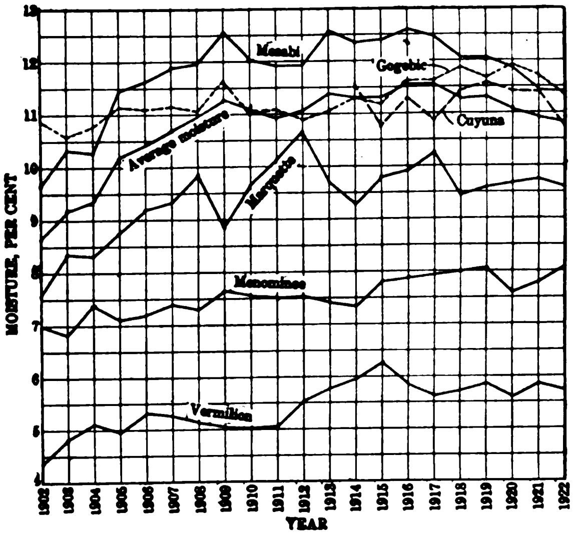

FIG. 5—Average moisture content of total tonnage of Lake Superior iron ore. (Prepared by Lake Superior Iron Ore Association.)

Fig. 4 shows the method by which this is done. The process has been described by W. L. Swart.[*] Briefly, it involves crushing to 1½ inch without any separation, followed by step-reduction to six mesh with reduction of non-magnetic material between the steps. One-third of the original material is thus rejected and the 6-mesh material, representing two-thirds of the original weight, contains 38 per cent iron. By further crushing and magnetic concentration, as shown in the flow sheet, it is finally reduced to a concentrate containing 64 per cent Fe, after it has been mixed with coal and sintered on a Dwight-Lloyd machine. The process is carefully controlled so as to obtain a concentrate of the desired grade with the minimum amount of fine grinding which is, of course, expensive on such hard material. The most notable features of the plant are the Davis magnetic spiral washers and rake washers which were devised for this plant. These devices, which are so admirably adapted to this purpose are described in detail by E. W. Davis[*] and A. B. Parsons.[†]

As the plant at last advises was not operating to full capacity, no cost figures have as yet been published. The essential features to be noticed, however, are that the original material contains only 27 per cent iron in the magnetic form and from it is produced a concentrate amounting in weight to 36 per cent of the crude ore, and containing 64 per cent Fe. The phosphorus has been reduced from 0.07 per cent in the original material to 0.027 per cent in the concentrate, or its ratio to the iron has been reduced to less than one-fifth that in the original material. The reason for this is, of course, that the mineral in which the phosphorus occurs, presumably apatite, is not magnetic. The iron content of the concentrate is fixed by the silica content; in other words, the aim is to make a concentrate that will not exceed 9 per cent in silica content and such a concentrate contains 64 per cent iron. A rough calculation indicates that such a concentrate in addition to a premium for its low phosphorus, is entitled to a premium of about $1 per ton for its high iron content.

The first example cited is of an ore from which the silica is easily and cheaply removed; the second example is of an ore from which the silica is removed with more difficulty and expense; the third example is of an ore of which no practicable means has as yet been found to reduce the silica content. On the Cuyuna Range, Minnesota, there are iron ore deposits that are high enough in manganese and low enough in phosphorus so that they might be used for the production of spiegeleisen, were it not for the unfortunate fact that they contain about 17 per cent SiO_2. On examining the ore under the microscope it is seen to have an extremely fine grained structure, the silica and metallic oxides being intimately associated. It goes without saying, almost, that no practical method of decreasing the silica content of these ores has yet been devised; the problem appears almost insoluble. As a fourth example of the removal of silica from iron ore the magnetic concentration plants of the Eastern United States may be cited. There are a number of such plants; one of the newest, at the Richard mine, Mount Hope, N. J., is described in detail by H. M. Roche.[‡] Magnetic concentrators for iron ore are discussed by S. Norton and S. Le Fevre,[§] and as so much has been written about the magnetic concentration of iron ores that only general principles will be referred to here.

Principles of Magnetic Separation.

A number of minerals are sufficiently para-magnetic so that they may be separted from other minerals by making use of this characteristic. Magnetite is strongly para-magnetic and is readily separated from other minerals if the magnetite and other minerals are in separate grains. The lumps of ore as mined are made up of a mixture and the chief problem is the crushing of the ore to produce separate grains and without doing unnecessary work—that is, to say, crushing the grains beyond the point at which they become separated. This is of course difficult to do and can only be approximated. Once the ore is properly prepared for the separation process the latter offers no particular difficulty.

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[*] Proceedings Lake Superior Mining Institute, vol. 23, 1923, pp. 111-116.

[*] "Magnetic concentration of Ore." Bulletin 9, Minnesota School of Mines, Experiment Station, 1921, 138 pp.

[†] Operations of the Mesabi Iron Company, Engineering and Mining Journal-Press, 117, 1924, pp. 202-210.

[‡] Engineering and Mining Journal-Press, vol. 115, 1923, pp. 923-932; 971-976.

[§] Bulletin, American Institute Mining Engineers, 1918.

The concentrated product thus produced is in a more or less fine state of subdivision, but it is not difficult to sinter it, and the present trend of opinion is that the good physical structure of the charge resulting from the use of this sinter increases the speed of smelting and reduces fuel consumption. Also it has been found that the blast furnace will operate satisfactorily on a charge wholly made up of such a sintered product. The problem therefore resolves itself, in a broad way, down to being able to make a sintered product at a cost which compares favorably with the cost of other iron-bearing material. If the sintered material is high in iron and low in silica its relative value should be computed in terms of the cost of making iron from it. If the price of sinter, computed in this way, exceeds the cost of making it, the beneficiation operation is a profitable one.

In conclusion, reference must be made to the fact that the reduction of iron oxide to iron, discussed in the preceding chapter, yields a para-magnetic product that may be easily concentrated magnetically. Such an operation may therefore be regarded as one primarily intended to reduce the silica content of the ore in its original state.

Removal of Water from Iron Ore.

Water is an impurity that is present in all iron ores, but the amount present varies widely. It is present in two forms, chemically combined with the minerals and physically held. It may be physically held in the pore spaces in the ore, in capillary passages between ore particles, and absorbed on the surface of particles of the ore.

The amount of water which an ore can contain without appearing visibly moist depends upon the physical structure of the ore. Hard, dense ore that breaks into large lumps will hold very little moisture, sometimes even less than one percent. But if this same ore is crushed into small particles, thereby increasing the ratio of its surface to its mass, the amount of water it will adsorb will be increased, so that the same ore which in large lumps was nearly free from water, will in fine powder hold much larger amounts without any appearance of being wet. In mining and shipping, a considerable proportion of even a hard ore is broken fine, and in the course of its long journey from the mine to the blast furnace the ore has ample opportunity to take up all the water it will hold. Another reason for high moisture content is that the impurities in the ore may have a large surface in proportion to their mass, and hold so much moisture that they raise the average of the mixture. For these reasons it is not uncommon to find the ore shipped from the "'hard ore" ranges of Michigan averaging 7 to 10 per cent moisture for the season's shipments. The lump ore from the Cliff Shaft mine, Ishpeming, Mich., averaged 0.50 per cent moisture in 1916, while the crushed ore averaged 1.50 per cent moisture. Less than 4 per cent moisture (average) in the ore shipped from the hard ore ranges is unusual, as is indicated by Fig. 5, prepared by the Lake Superior Iron Ore Association.

Hard and Soft Ores.

It may be well to point out here that the terms "hard" and "soft" as applied to iron ore in the Lake Superior district have a local significance, which may be confusing to outsiders. Quartz has a hardness of 7 and is, therefore, a little harder than hematite, which ranges in hardness from 5.5 to 6.5, hence it is correct to say that fine quartz sand, like sea sand, is harder than lumps of hematite. The local definition,* is that a soft ore is

> one which contains in place all fine or all hard material, or both, but after displacement it is disintegrated into a fine texture frequently containing a considerable amount of lumpy material, the percentage of which, however, is less than the fine. A hard ore is a firm compact mass in place, which breaks into hard lumps when blasted in mining.

A purist might object to this definition because it seems to state that an ore can be disintegrated into a texture, and that it may be simultaneously all fine and all hard material, but the intent of the statement is clear; the terms hard and soft, as used in describing Lake Superior iron ores, signify the degree of coherence, or of aggregation of their constituent particles, rather than actual hardness. In Alabama, on the other hand, hard ores are those high in lime, which are there more coherent.

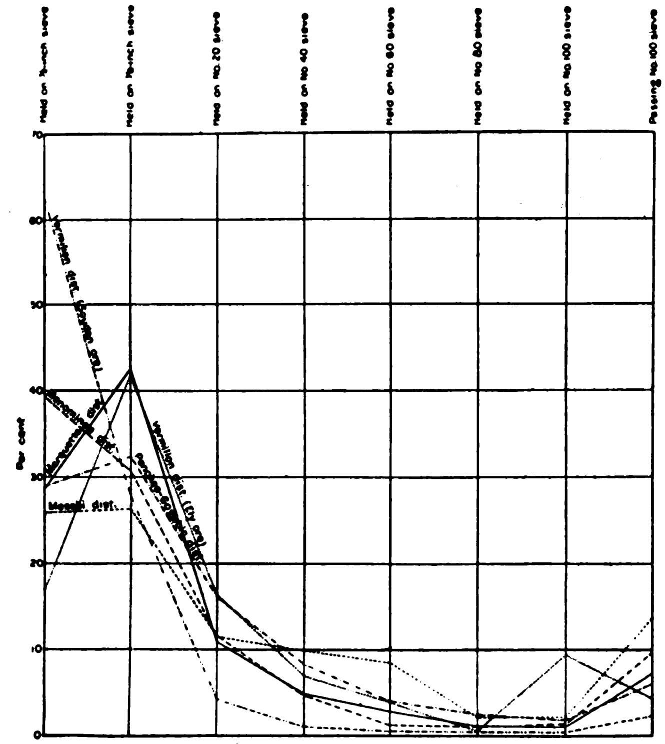

FIG. 6—Textures of Lake Superior iron ores as shown by screening tests of samples of 22,376,723 tons of Oliver Iron Mining Company. (After Van Hise, Leith, and Mead, U. S. Geol. Survey Mon. 52, 1911.)

Porosity of Ore.

Another factor that must be taken into consideration is the porosity of the ore, because the relation of surface to mass cannot be stated simply in terms of the size of particles. Pumice stone is a good example of a material which breaks into large lumps (and therefore in Lake Superior terminology would be considered hard) and at the same time has a higher ratio between surface and mass than more finely divided material. From the circumstances of its origin through removal of silica from the primary phase of the iron-bearing formations, the Lake Superior iron ore naturally has a large, though somewhat variable amount of pore spaces. Van Hise, Leith, and Mead* made a large number of determinations of the pore space in ores from the various districts, the results of which indicate as little as 1 per cent pore space in the hard, specular ores of the Marquette district, and as much as 40 per cent pore space in the soft ores of the Mesabi district. These authors were only interested in the pore space of the ore in place and for our purposes their results are deficient in failing to distinguish between the pore space of the ore in place and the pore space created by the disintegration of ore in mining and shipping. Hard specular ore with only 1 per cent of pore space, would, on being crushed to a fine powder acquire a large enough ratio of surface to mass to be able to adsorb considerable amounts of moisture.

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*"Methods for the Commercial Sampling and Analysis of Ore," prepared by Chemists' Committee of U. S. Steel Corporation, second edition, 1914.

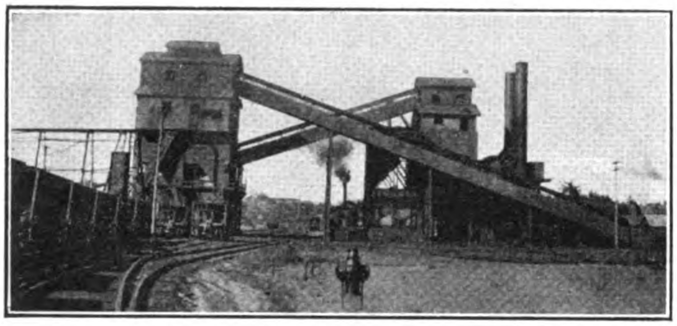

FIG. 7—Drying plant at Sagamore Mine, Minnesota.

The effect of size of particle on moisture content is indicated in Fig. 6, taken from Van Hise, Leith and Mead's work cited. The Soudan ore of the Vermilion district, which has a high percentage of ore retained on a ½-inch sieve, averaged 0.98 per cent moisture for the 1916 shipments, while, the average ore of the Vermilion district ranged from 4½ to 8 per cent moisture. The proportion of very small particles, those passing 100 mesh, is the most significant, however. A comparison of Figs. 5 and 6 shows that the districts fall in the same relative order as regards moisture content and proportion of material finer than 100 mesh except the Menominee and Gogebic, where the order is reversed. Inspection of the pore space charts in Fig. 6 shows, however, that the Gogebic ore has more pore space than Menominee ore, and reference to the average chemical analyses reveals that alumina in the Gogebic ores averaged nearly 2 per cent in 1906 and 1907, while the alumina in the Menominee ores was barely 1.5 per cent for the same two years. The presence of finely divided material in the ore as shipped, especially if it is of an aluminous nature may, therefore, have a profound effect on the moisture content of the ore, and leads, on the Cuyuna range, to the apparent paradox of washing the ore in water to reduce its moisture content.

Washing Ore to Reduce Moisture.

Ore from the Mahnomen mine that is too high in moisture, and consequently too low in iron natural, to ship, is sent to a concentrating plant on Little Rabbit Lake which was originally built by the Pittsburgh Steel Ore Company for reducing the silica content of its ore. The ore from the pit is dumped into a bin over a Barr chain grizzly, and the material from the bin elevated by a belt to the top of the mill where it passes through a 20-ft. revolving trommel with 1½-in. openings. The oversize from the trommel discharges over a picking belt and the picked ore goes to bins whence it is shipped as lump ore. The through product of the trommel goes to two 25-ft. log-washers, one-half to each. The tailing from the log-washers goes to waste. The log product goes to two vibrating screens which separate it into two sizes.

The reason for making two sizes is that when material of a variety of sizes is mixed together the smaller particles occupy the spaces between the larger particles, and this convert what would be open spaces into capillary passages that are able to hold water. In a collection of particles that are all the same size the voids are half the volume, but with different sizes mixed in the proper proportion so the small ones occupy the spaces between the larger, the voids can be reduced to a very small amount. Where the particles are all large and of the same size the only way in which the water can be held is by adsorption on the surfaces of the particles and it is gradually lost by evaporation if air is able to circulate through the mass. With a mixture of sizes the water is also held by capillarity in the small spaces between the particles. Hence, when the log product is divided into two sizes and allowed to drain it retains less water than it would if the two sizes were mixed together, and a marked decrease in water content is noted in the time it takes the loaded railroad cars to arrive at the docks on Lake Superior, where the moisture sample is taken. It is necessary to take precautions so that the water which is used to transport the concentrate from the screens to the bins will not deposit any muddy sediment on the concentrate, as this would defeat the purpose of dividing the concentrate into sizes, described above.

By this procedure, a concentrate corresponding to about 70 per cent of the original weight and containing about 8 per cent moisture, is recovered from material containing about 22 per cent moisture as mined. Although the recovery is only 70 per cent of the original weight it is $\frac{780}{644}$, or 80 per cent of the solids of the original material. The following calculations will indicate the benefit derived from this operation:

One ton of original material containing 46 per cent iron natural and 22 per cent water:	
Value at Lake Erie port	$4.47
Deduct freight to Lake Erie port	1.74
Value at mine	$2.73
0.7 ton of concentrate containing 51.5 per cent iron and 8 per cent water:	
Value at Lake Erie port (0.7 × 5.55)	$3.88
Deduct freight (0.7 × 1.74)	1.22
Value at mill	2.66
Deduct cost of washing	0.12
Net value at mine	$2.54

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*Van Hise, C. R., and Leith, C. K., "Geology of the Lake Superior Region." Monograph 52, U. S. Geological Survey, 1911, p. 481.

At first glance it would appear that the operator had lost 19 cents per ton by washing his ore to eliminate moisture, but the real point is that ore containing 46 per cent iron natural and 22 per cent water is unsaleable, while 55 per cent ore containing only 8 per cent water is readily saleable. The apparent value of $2.73 per ton of original material at the mine is only a fiction, for it cannot be sold at all, whereas the value of $2.54 for 0.7 ton of concentrate is a reality.

Drying Iron Ore.

The drying of iron ore prior to shipment is not, as a rule, simply to save the freight on useless water, but to bring the natural iron content up to a point at which the ore will command a satisfactory price. The freight charges on the water are, of course, saved, and if the price received from the dried product, less the cost of drying is more than the value of the undried ore the drying operations are warranted. The analysis is not quite so simple as this, however, for in putting the natural ore through a drying plant there is a dust loss that must be included in the drying cost. As a rule the dried ore is dusty and not only is subject to further loss in the handling operations involved in transportation to the smelting plant, but gives rise to objection by the men handling it. At one drying plant on the Cuyuna Range the ore is dried from its original moisture content of about 20 per cent down to 8 per cent moisture, and is mixed with undried ore at the docks so as to give an average of 12 per cent, thus decreasing the dust.

Drying plants to reduce the moisture content of iron ore have been built at the Hollister mine, Crystal Falls, Mich.; the Brunt mine, Iron Mountain, Minn.; the Whiteside mine, Buhl, Mich.; the Wakefield mine, Wakefield, Mich., and the Sagamore mine, Crow Wing County, Minn. Fig. 7 shows the plant at the last named.

The drying tubes at the Sagamore plant can be indistinctly seen at the right of the illustration. The ore particles are exposed to the heat for about 20 minutes in the course of their passage through the tubes and emerge at a temperature of about 140 deg. F. The coal consumption is stated as 8 lb. per ton of ore dried from 20 per cent moisture down to 8 or 10 per cent. The dried product is screened into three sizes, two of which are shipped and the dust is stockpiled for future treatment.

Conclusions as to Moisture in Ore.

In conclusion, it may be said that the moisture content of iron ores derives most of its importance from the method employed in reckoning the value of iron ores. Non-Bessemer ore is sold at base price for 51.5 per cent iron content natural, and for ore below this grade, increasing deductions are made from the unit price. An increase in the water content brings down the natural iron content and therefore the price. As a rule, much lower in iron than the base cannot be sold at all, so that drying a high moisture ore may serve to bring its iron content up to where it can be sold, as well as increase the unit price.

Moisture in the ore cuts little figure at the blast-furnace. The moisture is evaporated off near the top of the stack, and some operators prefer high moisture in order to keep the top cool. Others add moisture to the raw materials to keep down the dust. The buyer of ore therefore does not concern himself with moisture, but the ore producer has to, because the price of his ore is figured from the iron content natural and freight is paid on the moist weight. Under these conditions it sometimes pays to dry the ore before shipment.

(To be concluded)

Offers Research Work

Students are afforded an opportunity to engage in investigational work along mining and metallurgical lines as a result of a series of co-operative agreements effected between the Bureau of Mines and various universities and colleges for the maintenance of a number of research fellowships. For the college year 1926-1927, more than thirty fellowships in eight institutions will be awarded. The institutions offering the facilities are the University of Alabama, Tuscaloosa, Ala.; Carnegie Institute of Technology, Pittsburgh; University of Washington, Seattle; University of Arizona, Tucson, Ariz.; University of Utah, Salt Lake City, Utah; University of Idaho, Moscow, Idaho; University of Missouri, Rolla, Mo.; and University of Nevada, Reno, Nev. Detailed information as to the terms of the different fellowships can be obtained by applying to the engineering and mining schools of these institutions.

Double Retort Boiler Stoker

The Detroit Stoker Company, Detroit, Mich., has developed a double retort boiler stoker, as a means of meeting the demand for a mechanically-driven stoker of the multiple retort type adaptable to boilers of 300 to 500 hp., and having the side cleaning feature so that ashes and refuse can be removed at the front. The normal speed of the coal feeding mechanism is greatly reduced, insuring better ignition, complete combustion and high capacities. Complete underfeed action is obtained with larger active grate area.

The stoker is said to have been found extremely flexible and capable of going from a banked fire to full rating. A basement or tunnel is not required, and the ashes can be removed at the front directly onto the boiler room floor. Comparatively little excavation or concrete work is required to install the new type stoker under boilers already in use.

New Use for Stainless Iron

In the synthetic process of making nitric acid, as developed by the Fixed Nitrogen Research Laboratories at Washington, certain containers are necessary in producing the acid on a commercial scale. A large American company, which is about to install this process on a fairly large scale, has found that stainless iron is entirely unaffected by any phase of the nitric acid process. They have, therefore, decided to equip a new plant entirely with containers and other apparatus made of stainless iron for the carrying on of the process.

Homestead to Install New Beam Mill

The new "I" beam mill, the second of its kind in the United States to manufacture beams larger than 27 inches, is being completed at the Homestead works of the Carnegie company. The mill will roll sizes up to 36 inches, and will be in operation within a few months. It is a part of the improvement program that will cost several million dollars.

Manufacture of Charcoal Iron at Mysore

(Continued from page 253)

The method of operation is as follows. The gas enters the stoves through a Bradshaw gas burner, which is considered the most efficient of all types, for burning blast furnace gas. Air is admitted through a venturi like tube mixed with the gas in the ignition chamber, where the mixture ignites. The hot gases pass up the stove combustion chamber down through the checker brick, out through the chimney valve, which is a goggle type valve with a butterfly valve for regulating the draught. The gases, after passing through the chimney valve, enter the chimney flue, which leads them into the chimney. The temperature of the gas in the stack is about 500 deg. F., the remainder of the heat generated by the burning gas having been absorbed by the checker work of the stoves, less radiation loss. This is continued for two hours, when the gas is shut off, and the cold blast valve, an ordinary gate valve with an equalizing pressure port in the gate, opened and the air blown through in the opposite direction.

The cold blast passes up through the brick checkers down through the combustion chamber and out through the hot blast valve, a vertical lift valve operated by a hand chain and wheel with water-cooled steam and seat into the hot blast main and through the tuyeres into the furnace, picking up the heat from the checkers enroute that they absorbed from the burning gas The hot blast in bustle pipe is usually maintained at about 1,000 deg. F. In the beginning of the blowing period of a stove, if the blast is too hot, cold blast is allowed to mix with it through a by-pass, so as to maintain as near constant pressure as possible throughout the period of blowing.

Passing from the furnace through a downcomer of ⅜ in. steel plate 3 ft. 9 in. in diameter with a 4½-in. fire brick lining, the gas enters a ⅜-in. steel plate dust catcher which is also lined with fire brick, where the dust is expelled by the velocity of the gas. Above the downcomer, is a steel plate bleeder pipe having a valve at the top with a sealing pressure of ¾-lb. per sq. in. Should an explosion occur, within the furnace, the bleeder valve, as well as the explosion doors on gas seal, downcomer, dust catcher and gas main being open, create a vent, thus relieving pressure and averting the possibility of serious danger.

From the dust catcher, the gas issues to both the stove gas main and boiler gas main from a steel plate drop leg and is dissipated either in the stoves or under the boilers. Then there is the system of cooling for the furnace, for which no less than 500,000 gal. of water per day are required. For this purpose there is an efficient system of water supply, while a special service tank is maintained with a reserve of 10,000 gal., which will be sufficient for half an hour's use when the pumps have been closed down, as may sometimes be necessary, for minor repairs.

We now come to the cast house. It is a structure 50 ft. wide by 100 ft. long, and is filled with sand for making the pig beds with the iron runner in the center. The two sides of the cast house are used alternately (each half being large enough to hold one cast), the beds being made up on one side while the iron is being removed from the other. Thereafter the slag is turned into a sand bed, from which it is loaded into the cars and taken to the dump; and finally it goes to the iron storage yard, whence it is either transferred to the foundry or loaded into cars and shipped to the market.

Looking at the administration of the works, it is seen that on them roughly speaking about 4,000 persons under all heads find employment. The management is conducted mostly by indigenous talent in all branches.

The iron works ranks as the foremost of the big industrial schemes which were conceived by Sir M. Visvesvariya, the then Prime Minister of the Mysore State and materialized during his premiership. The iron works is financed and worked by the Government of Mysore.

Safety Work in the Steel Industry

Safety is an intensely positive, not negative principle. The leaders of the safety movement have never used the slogan "safety first" except in the steel mills, railroad shops and factories where it was first and rightly used. As a general philosophy of life, safety does not mean a timid shrinking from the strenuous life normal to every healthy person, it means saving life to the full, but living it the right way which is the safe way. Safety forbids nothing except what is forbidden by common sense and consideration for others.

In the steel industry, birthplace of the modern safety movement, the fatalities per million hours worked have decreased 50 per cent in the past ten years. This is the average of the group of companies doing safety work. Individual companies in the steel and other industries have reduced the frequency and severity of accidents by 75 per cent and even 90 per cent. The direct economic savings have exceeded the cost of the safety work, to say nothing of the improvement in morale.

Today accidents are a more prolific cause of suffering and death than war. During the 19 months in which the United States was more or less actively engaged in the world conflict, the total mortality among American soldiers from all causes was 77,101. During the same 19 months, 136,000 persons lost their lives through accidental means although they were engaged in the pursuits of peace.

Industrial accidents cost the business men of America more than a billion dollars annually, points out C. B. Scott, president of the National Safety Council, who states that most of this loss can be saved, as accidents don't happen, but are caused by hazards which can be eliminated through educational methods and safeguards. Mr. Scott's hope that more business men will enlist in the country-wide safety movement is worthy of consideration.

Heavier Rails to Support Heavier Traffic

The rail is catching up with the locomotive. Orders placed recently show an increasing number of carriers calling for rail with a weight of 130 and 136 pounds per yard compared with the 100-pound weight in common use on some of the larger roads prior to the resumption of private control and to 80 and 90 pounds on the roads of lighter traffic. These orders follow closely an announcement by the American Iron and Steel Institute that the production of rails of 100 pounds or over in 1925 established a new record.

Measuring Drawing Properties of Metals*

The Authors, by Co-ordinating Their Laboratory Tests with the Results of Actual Drawing Operations, Have Endeavored to Determine the "Drawability" of Metals

By WM. S. MONTGOMERY, JR., and E. RAY ENDERS, JR.†

AS a contributory part of the program outlined for research pertaining to the cutting and forming of metals, headed by Mr. B. H. Blood, Chairman of the A.S.M.E. Special Research Committee on the Cutting and Forming of Metals, this series of tests was run and this report written.

The work was suggested by Prof. J. O. Keller, head of the Industrial Engineering Department, Pennsylvania State College and a member of the above-mentioned committee, and supervised by him throughout. It was in the nature of a continuance of the work which he did at the plant of Pratt & Whitney during the summer of 1924, the results of which were published in the Mid-November, 1924, issue of "Mechanical Engineering" under the title "A Comparison of the Herbert Pendulum Hardness Tester with Other Hardness Testers." Professor Keller found a close correlation between the Rockwell hardness tester, the Brinell method of hardness testing, and the Herbert pendulum time test. He also used the Herbert scale test and the work-hardening test, but found that they tested properties different from those dealt with by the other methods.

It was with the idea of ascertaining whether or not these or any other measurable properties bear any relation to the drawing properties of the metals, that the experiments about to be described were performed.

Many concerns engaged in pressed-metal work are using some form of hardness testing in an effort to predetermine the drawing properties of metal—or "drawability," as it will be designated hereafter in this paper; but for the most part the methods employed have been highly unsuccessful, causing an enormous waste of metals which failed in the forming or drawing process. It was that particular phase which was studied by the authors during their research, and their aim was to help somewhat in the large amount of research necessary before some infallible method is discovered for predetermining drawability.

There are a great number of conceptions of hardness, and these lead to confusion of terms. There is the Moh scale or scratch hardness, the scleroscope or elastic hardness, the Rockwell and Brinell or indentation hardness, the Herbert flow hardness, work hardness, and work hardening, machinability, plastic indentation, etc. However, it will be sufficient to find and measure that property or those properties which are factors of drawability, being careful not to confuse the terms used, and not to think of them as definitely related under the all-inclusive word "hardness."

The Boston Pressed Metal Company, being much interested in the tests proposed, offered marked samples of metals such as they might buy for drawing purposes, the drawing qualities of which were unknown by the college. These were to be tested by any of the available methods; and the opinions of the investigators as to their relative and absolute "drawability" were to be determined. The Boston Pressed Metal Company knew, by actual shop tests, those samples which could be drawn and those which could not, and thus it was possible to check the results of the research by a very practical method—the actual process for which the tests were conducted.

A series of scleroscope tests were conducted on each specimen; but since many of them were so thin as to be materially affected by the character of the anvil, no great value was attached to readings.

All Rockwell tests were performed with the 1/16-in. steel ball and 100-kg. weight, so a good comparison of values was obtained. However, some of the sheets were too thin to be tested in this manner, since the depth of penetration approximated the thickness of the sheet, pressing the metal in the lower part of the impression against the anvil, and giving a reading composed of the resistance to indentation of the metal and of the hardened steel anvil. Since by Professor Keller's research the Rockwell and the Brinell methods checked so well, the Brinell numbers were computed from the Rockwell numbers by a table found in the handbook accompanying the Rockwell machine and reproduced here as Table 1.

TABLE 1—CONVERSION OF ROCKWELL B-SCALE HARDNESS NUMBERS TO BRINELL NUMBERS

Rockwell B-scale.	80	75	70	65	60	55	50	45	40	35	30	25	20
Brinell numbers..	151	138	126	117	108	101	95	88	83	79	74	70	67

There were no variations found due to the minute particles of carbon and to the variations in indentation hardness of various grains. Evidently the ball covers an area large enough to mechanically average these variations, which are inevitable, and to give uniform readings over the entire surface. This feature, in addition to its simplicity, makes the Rockwell machine a valuable one for those who desire to learn only the indentation hardness; but, according to pressed-metal manufacturers, this is not a solution of the problem of drawability. It indicated, for example, that specimens Nos. 4 and 5 will draw well, but according to the experience of the Boston Pressed Metal Company, they will not draw at all. Specimen No. 7 was shown to possess poor drawing qualities, but it really is one of the best of those examined.

In the use of the Herbert pendulum, the difficulties which have been mentioned by so many investigators were again experienced. It is very difficult to balance the pendulum, and even when this has been accomplished, for no apparent reason it will suddenly give erratic readings and be again out of balance. Then, too, the slightest air currents materially affect the readings; and it is necessary to perform the tests in a closed room, being careful not to allow the apparatus to be struck even by the current of air set up by natural breathing.

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*The 1925 A. S. M. E. student prize award paper. Reprinted from Mechanical Engineering.

†Students, Department of Industrial Engineering, School of Engineering, Pennsylvania State College. Members of Student Branch of A. S. M. E.

The ball upon which the pendulum moves is only 1 mm. in diameter, which is hardly large enough to cover an area on the specimen which will average the variations in the composition, size, and orientation of the individual grains. This statement is well borne out by photomicrographs of the ball impression in various metals taken by Mr. Herbert and Professor Keller. In the extreme case of two samples, the structure of which is shown later in this report, the ball would scarcely cover one grain and might easily be measuring the hardness of only one grain or of several grains in one of the infinite number of proportions possible.

It was also found that a slightly roughened surface had a marked effect upon the consistency of readings. Even the surfaces of some hot-worked metals were found so uneven that the ball was in a depression, on an elevation, or rolling up an incline. It was not possible to grind the surface for fear of changing the structure by heat-treating or work-hardening.

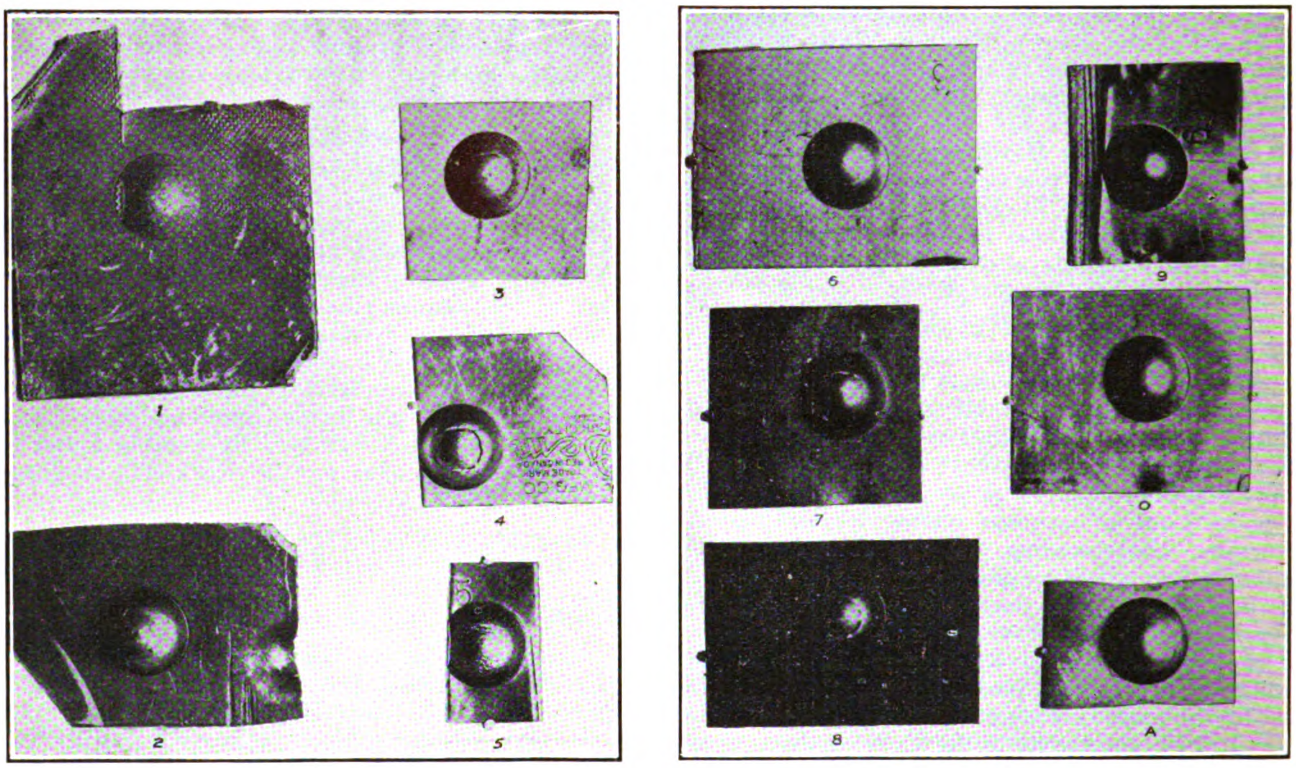


FIG. 1—Erichsen-machine tests of drawability of various specimens of sheet metal.

Because of these variations from the correct readings, all of the tests performed with the Herbert pendulum were repeated on each specimen from 15 to 30 times in order to make certain of the accuracy of the data obtained.

For the time test the pendulum is adjusted so that its center of gravity is 0.1 mm. lower than the center of the supporting ball. The specimen is accurately leveled and the pendulum gently placed upon it. By means of a feather, the operator moves the pendulum so that the bubble travels over five or ten divisions of the scale. After ignoring the first few swings, the period of 10 swings or five complete oscillations is timed with a stop watch, and the number of seconds required for these oscillations is called the "time hardness" number. As proved by Professor Keller and Mr. Herbert, there is a definite relation between this number and the Brinell number. This ratio, expressed by means of a formula, is

$$B = 10\ T \quad (\text{when } T > 33^1/_3)$$
$$B = 0.3\ T^2 \quad (\text{when } T < 33^1/_3)$$

where B is the Brinell hardness number and T the time hardness number.

No particular difficulties, except those previously mentioned, were experienced in conducting this test; and in fact it is the easiest test performed with the pendulum. Since it measures the same kind of hardness as the Brinell method and the Rockwell method, and since it is much more difficult to operate than either of these, the pendulum is not valuable because of this test alone. One advantage, however, of the pendulum test over both the Brinell and the Rockwell is that on hard polished specimens the pendulum does not noticeably mar the surface.

The scale test may be performed in two ways giving materially different results but apparently measuring the same property of the metal. The original scale test is accomplished by setting the instrument on the specimen in the horizontal position and gently tilting it with the hand until the bubble comes to either 0 or 100, depending on whether it has been tilted clockwise or counterclockwise. It is then released; and the number of graduations which the bubble traverses during the first swing is the "scale hardness" number. Another method of conducting the test is to set the pendulum initially on the specimen so that the bubble is at 0 or 100, and then release it. This gives a scale hardness which does not include the work hardening caused by moving the pendulum so that the bubble travels from 50 to 0 or 100.

In both of these methods the personal element is a large factor in the reading obtained. It is very difficult to set and move the instrument in exactly the same way every time. That objection could be eliminated by the use of apparatus which would give a uniform setting; but the tests did not give an indication of drawability. They indicated, for example, that No. 4 would draw very well, but as a matter of fact it was one of the two poorest specimens for this work. Several of the other results were also very much in error as to the drawability.

The flow number, as described by Mr. Herbert, is obtained by dividing the "scale hardness" number by the "time hardness" number. This is admittedly rather a vague property and, for the authors' purpose, was found quite useless. Practically none of the indications were later found correct.

In the work-hardening test the pendulum is set on the specimen so that the bubble is at 0 or 100. It is allowed to swing, and the number of graduations passed over by the bubble is recorded. Just as the bubble stops moving the pendulum is grasped and is forced to continue its swing until the bubble is at the other end of the scale. It is then released and the reading taken. This is continued until the size of the numbers ceases to become larger with each successive swing. The numerical increase in hardness from the original value to the largest value obtained is prefixed with a letter indicating the number of the swing at which the largest reading was obtained. Most of our specimens gave the largest reading during the first swing after the original one. Hence the increase was prefixed with the letter "A."

The theory involved is that the ball mechanically works the metal, and while working it registers the increase in indentation hardness. This is a very logical procedure for determining drawability, since it seems highly probable that the fracture of metal during a drawing process is caused by the work-hardening capacity which hardens the metal to a brittleness. However logical it seems, the results obtained were quite different from the actual drawability. Nos. 4 and 5 were again placed as good drawing specimens and several of those with excellent drawing properties were classed as poor.

It may be that the error is caused by slippage of the ball in its indentation, for the authors are thoroughly convinced that this occurs. A more or less inaccurate proof follows.

Pendulum swings through approximately 27 deg.

Diameter of ball = 1.0 mm.

Circumference of ball = $\pi d = 1.0\pi = 3.1416$ mm.

Travel of ball in horizontal straight line, assuming pure rolling, $= T$

T : circumference of ball :: 27 deg : 360 deg.

or

$$T = \frac{3.1416 \times 27}{360} = 0.2327 \text{ mm.}$$

Total length of impression $= T +$ radius of ball in 0 position + radius of ball in 100 position

$= T + 2r$

$= 0.2327 + 1$ mm. $=$ 1.2327 mm. or 1.233 mm.

The ratio of length of impression to its width cannot be less than 1.233 to 1.0 because the largest possible width is 1.0 mm. and the smallest possible length, if the ball does not slip, is 1.233 mm. Any variation from these extremes tends to decrease the ratio and make the contention that slippage does occur more apparent.

By actual measurements of a number of photomicrographs, the ratio of length to width was found to be about 1.94 to 1.0. Since the theoretical ratio cannot exceed 1.23 to 1.0, there is some distance there which can only be accounted for by admitting slippage. It will be noticed that those inaccurate measurements were taken in the direction which was most disadvantageous to the substantiation of the proof; and that the possible irregularity in the line of swing of the pendulum increases only the width and not the length as measured on the photomicrographs. Then if irregularity has occurred, it has increased the width and decreased the ratio and does not at all weaken the proof, crude as it may be.

The tests conducted on the Erichsen machine came nearer to answering the author's question than those on any other testing machnie.

The Erichsen machine for testing metal sheets and strips has as its underlying principle the tensile test. The sheet or strip to be tested is clamped in the machine and its thickness is read. By means of a large hand wheel, a smooth semicircular dome forces the sheet out through the die which holds it. The inventor stresses three points in connection with the test: (1) After the thickness has been measured, the handwheel is turned back five small divisions on the scale in order to give the test piece a certain amount of play. A clutch is now pushed in and, by turning the handwheel to the right, a bulging will be immediately noticed in the mirror. (2) Watch the image in the mirror carefully until the point of fracture is reached. The character of the dome of the specimen is very important. In general, a smooth dome indicates a sheet of good drawing qualities, while a rough dome indicates large grain size due to overannealing and a sheet of no drawing qualities at all. (3) The extent a sheet draws to fracture, plotted against its thickness, gives an "Erichsen value." Here the authors were momentarily brought to a halt, for, as far as they could ascertain, the inventor of the Erichsen machine had devised no way of comparing sheets of different thicknesses and different compositions.

Working along this line the authors developed a "drawability scale" in the following manner: A tangent was drawn to one of the Erichsen-machine curves for brass of excellent drawing qualities, and a perpendicular was erected to this tangent. From the points obtained by plotting thickness against draw to fracture, lines were drawn parallel to this perpendicular, and by actually scaling along this line the authors arrived at what might be called a percentage of drawability, calling the good brass points 100 per cent. This was at best a rather crude method, but further investigation in that direction should be of value to Erichsen-machine manufacturers and users, as the result from one drawability scale checked fairly well with the report on drawing qualities sent to the authors later by the Bosten Pressed Metal Company.

The Erichsen test failed mainly in not picking sheet No. 2 as one of excellent drawing qualities.

It did very well in picking Nos. 4 and 5 as sheets having no drawing qualities whatever (rough dome

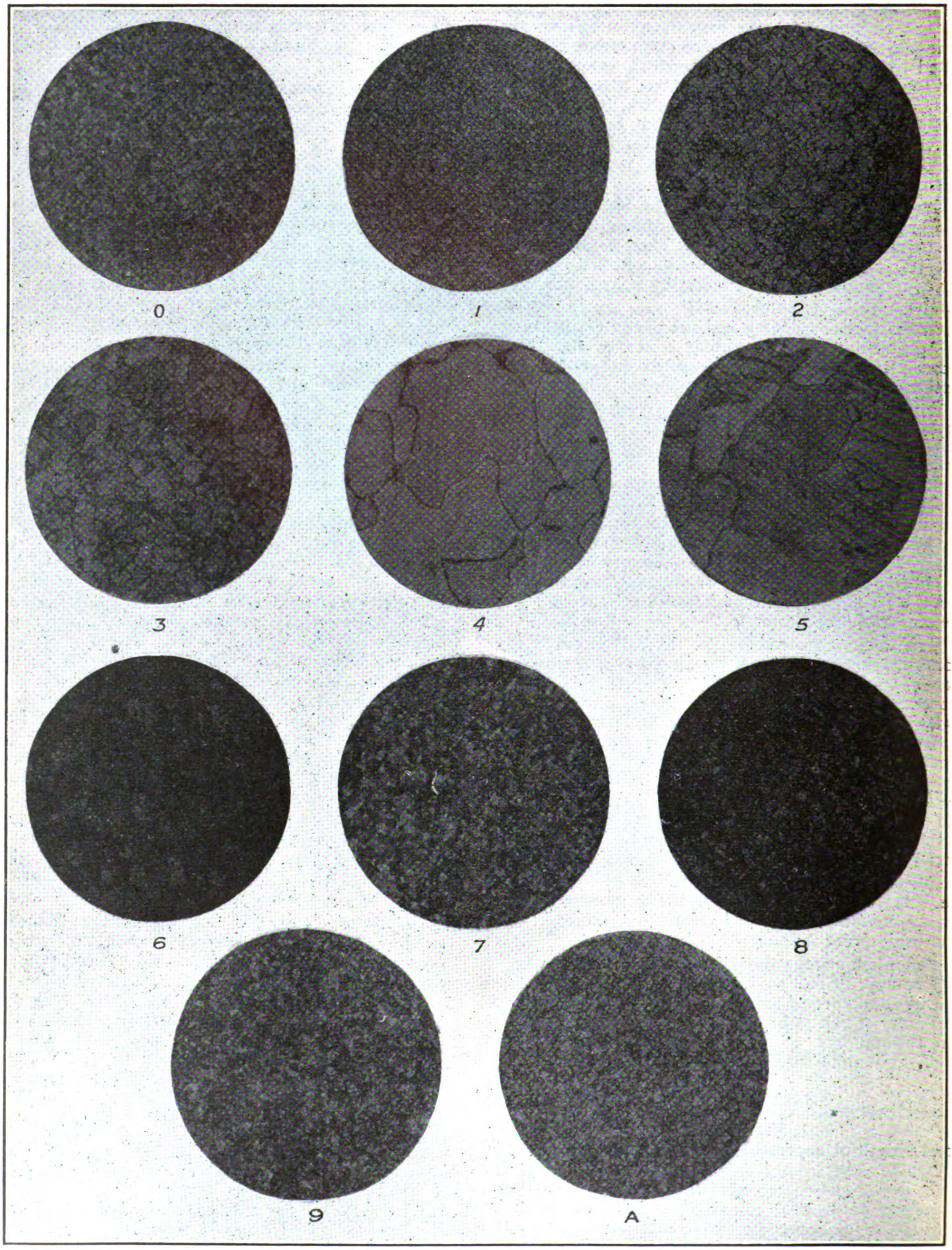


FIG. 2—Photomicrographs of specimens of sheet metal tested for drawability. Magnification, x 70. (All specimens etched in a 4 per cent solution of nitric acid and alcohol.)

showed large grain size due to overannealing), and in picking No. 6 as a sheet of very poor drawing qualities.

Photomicrographs of metal in the hands of any person who understands them may be of infinite value to manufacturers of metal products. It has only been recently that photomicrographs have come to be widely used, and many of the older engineers know little or nothing about them. The authors feel confident, however, that their future is assured, for they proved to be a great aid to the authors in helping them to form decisions which later were found to be correct.

TABLE 2—DATA OBTAINED IN DRAWABILITY TESTS OF METAL SPECIMENS

Sample number	Scleroscope values	Rockwell	Herbert time test	Brinell numbers calculated from Herbert time test	Herbert scales	Herbert work hardness	Herbert flow numbers	Erichsen Values			Character of Erichsen dome
								Thickness	Fracture	Scale value	
0	25	57.5	16	77	25	A10	1.34	0.775	9.0	0.62	Smooth
1	17	55	17.7	94	21	A39	1.38	Specimen too thick			
2	17	47.5	16.2	79	23	A34	0.915	3.04	9.3	0.42	Smooth
3	17.5	(a)	16.1	78	25	A18	1.38	0.54	8.3	0.67	Smooth
4	23	29	15.1	69	15	A 6	1.45	1.43	10.2	0.62	Very rough
5	24	38	15.6	73	23	A 9	1.50	1.50	9.85	0.58	Very rough
6	32	79	19.6	115	30	A33	1.26	1.49	8.4	0.48	Rough
7	27	64	17.2	89	21.5	A11.5	0.98	0.90	9.8	0.66	Very Smooth
8	27	59	18.1	99	19.5	A11	0.925	1.39	10.85	0.69	Very Smooth
9	12	(a)	13.0	51	12	A 4.5	1.47	0.33	11.3	0.89	Very Smooth

(a) Specimens too thin.

The sheets on which the investigations were conducted (with the exception of No. 9 brass) were all very low-carbon steels. No. 7 was a little higher in carbon content than the other sheets.

Referring now to the photomicrographs, it may be easily seen that in some cases they alone indicate the drawing qualities of the sheet. For instance, Nos. 4 and 5 are eliminated at once as their extremely large grain size prohibits drawing. Any draw or bend of these two sheets, no matter how slight it may be, causes them to break along the grain boundaries and makes them valueless. Similarly, a careful inspection of Nos. 1, 2, 7, 8, and 10 shows them to be low-carbon steels with very small grain size, which is a necessary quality for a good draw. No. "A" shown in this connection is a low-carbon steel of excellent drawing qualities which the authors include in this report merely for purposes of comparison.

As regards Nos. 3 and 6, no definite decision could be made from the photomicrographs alone, but tying them in with the results obtained on the various testing machines, No. 3 was found to be fairly good and No. 6 very poor for drawing.

As a matter of fact, the authors feel that it would be rather dangerous to base a decision as to the qualities of a metal on a photomicrograph alone. Other qualities entering in, and it would seem that the safest thing to do is to base the decision on the photomicrograph in connection with the reading of some testing machine, the type of machine depending upon the quality in the metal that it is desired to measure.

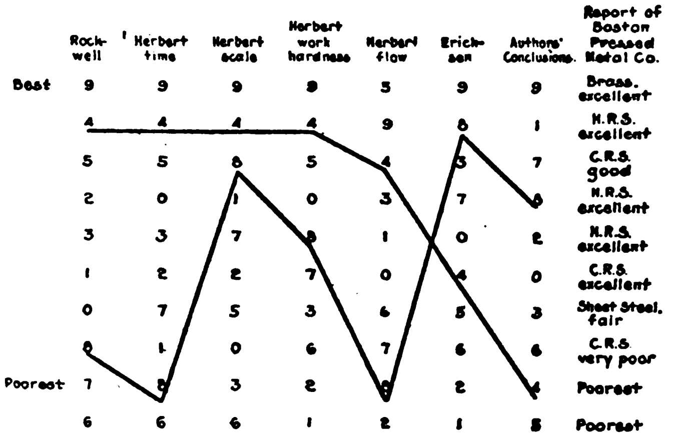
Table 3 give the drawability scale as obtained from the best at the top to the poorest at the bottom. The lines drawn show how the various tests changed their placement in the cases of two of the specimens. Following the column giving the authors' conclusions are the determinations of drawability as found by practice in the plant of the Boston Pressed Metal Company. It is not to be assumed that the gradations are equal between the specimens as rated and that there is any way of telling how much the metals will draw, other than by describing them with such vague adjectives as "very good," "good," "poor," "very poor," etc. However, for the manufacturer this will be sufficient until a better method is found.

An endeavor to explain the various ways in which the authors arrived at their conclusions is now in order. In the case of sheet No. 1, great difficulties were experienced in obtaining accurate readings from both the pendulum and the Rockwell tester due to the rough, uneven surface of the specimen. It was too thick to test in the Erichsen machine without special dies, and consequently the authors' opinion was formed in this case mainly through a careful inspection of the photomicrgraphs, which they interpreted to show a low-carbon steel of very fine grain structure. They rated this sheet as one that would draw well.

With sheet No. 2 much the same difficulties were experienced as in the case of No. 1. However, the authors were able to perform an Erichsen test which gave a low Erichsen value. A photomicrograph showed the sheet to be a low-carbon steel with a fine grain structure. These two points combined with the fact that there is a striking resemblance between the photomicrographs of No. 2 and No. A led to the selection of No. 2 as a sheet that would draw well.

The pendulum and Rockwell machines gave No. 3 a rather central position between the two extremes 9 and 6. The Erichsen gave a high Erichsen value and supposedly indicated a sheet of excellent drawing qualities.

TABLE 3—COMPARISON OF RESULTS OBTAINED BY VARIOUS TESTS



	Rockwell	Herbert time	Herbert scale	Herbert work hardness	Herbert flow	Erichsen	Authors' Conclusions.	Report of Boston Pressed Metal Co.
Best	9	9	9	9	5	9	9	Brass. excellent
	4	4	4	4	9	8	1	H.R.S. excellent
	5	5	8	5	4	3	7	C.R.S. good
	2	0	1	0	3	7	8	H.R.S. excellent
	3	3	7	8	1	0	2	H.R.S. excellent
	1	2	2	7	0	4	0	C.R.S. excellent
	0	7	5	3	6	5	3	Sheet Steel. fair
	8	1	0	6	7	6	6	C.R.S. very poor
Poorest	7	8	3	2	8	2	4	Poorest
	6	6	6	1	2	1	5	Poorest

A study of the photomicrograph, however, led the authors to believe that while the sheet was a low-carbon steel, the grain size was a little large in comparison with the ones they had already picked as good drawing sheets. Sheet No. 3 was designated as one of fairly good drawing qualities.

Sheets Nos. 4 and 5 are so similar that they will be treated together. Here the pendulum and the Rockwell testers failed singularly in an effort to measure drawability, for both of them on all tests gave low readings which seemed to indicate sheets of excellent drawing qualities. The Erichsen machine performed excellently here, for the moment the sheet started to draw, the surface of the dome roughened. At the point of fracture (a low Erichsen value incidentally) the surface of the dome was very rough and it could be seen with the naked eye that the drawn part of the sheet had actually broken apart, along the grain boundaries. The absurdly large grain structure is also very well brought out by the photomicrograph.

Sheets Nos. 4 and 5 were designated as steel of no drawing qualities at all.

All the testing machines but the Erichsen gave sheet No. 6 the highest reading, meaning the poorest one for the drawing purposes, and this is correct. A low "Erichsen value," a rough dome, and a peculiar photomicrograph showing a low-carbon steel of rather large, irregular grain structure led to the rating of No. 6 as a sheet of few or no drawing qualities.

Due to a high Erichsen value and a photomicrograph showing a fine, even grain structure, the authors rated No. 7 as a sheet of excellent drawing qualities. In this decision they were slightly in error, for while the Boston Pressed Metal Company rate this steel as one of good drawing qualities, they point out the fact that there is danger of cracking in a long draw due to a slight excess in carbon content over the ordinary carbon content for good drawing sheets.

A high Erichsen value with a corresponding good photomicrograph led to the rating of No. 8 as an excellent drawing sheet, despite the fact that the pendulum and Rockwell testers gave it high "hard" readings.

All the testing machines used combined in picking No. 9 as the best drawing sheet. This one gave a very low "work hardening" value on the pendulum, a low Rockwell reading, a high Erichsen value, and a very smooth dome. This brass sheet was the best-drawing one of the lot.

No. 1 was also rated by the authors as a good drawing sheet. With it they found quite the same conditions existing as with Nos. 8 and 7. The pendulum and Rockwell tester gave it high, poor-draw readings, while the Erichsen-photomicrograph combination led them to designate it as a sheet of good drawing qualities.

It is the opinion of the authors that at present the best method of measuring the drawability and ductility of sheet metal is the Erichsen machine used in conjunction with photomicrographs.

The research just completed is only a very small portion of that necessary to a satisfactory solution of the problem of drawability. The Erichsen machine came very close to providing a correct solution, and further investigation with it would probably be most valuable.

Since this machine seems to be based on the elongation phase of the tensile test, that test might well be given some attention. This may be elongation per unit length or elongation per unit length per unit of cross-sectional area. It will probably be necessary to change the standard testing machine so that it will read elongation as accurately as does the Erichsen.

Another series of tests might well be conducted on a machine conceived of by the authors, the basic principle of which is that metal, when deformed, tends to harden; and it is this hardening which presages failure.

An apparatus might be constructed by which a metal could be tested for indentation hardness, deformed by a certain number of length units in tension (or a certain number of degrees in bending), and then tested again for indentation hardness. The metal will have hardened considerably, and this may be expressed in absolute units or in a percentage of the original hardness; and the results may be found very valuable in determining drawability. The authors conducted a few very crude tests of this nature in connection with a Rockwell machine, and found that those metals which would not draw well hardened most rapidly; and so they are convinced that such a machine offers an attractive field for designers and research men.

In conclusion, the authors wish to thank the Pratt & Whitney Company for the use of their Herbert pendulum, and Herman A. Holz, Inc., for the use of the Erichsen sheet and wire-testing machine. They are also indebted to the Boston Pressed Metal Company and to the late Douglas P. Cooke for supplying the samples upon which the tests were conducted, and for the interest shown by them in the investigation. Especially, however, is credit due to Prof. J. O. Keller, Head of the Industrial Engineering Department of the Pennsylvania State College for suggesting the research and for his enthusiastic interest, without which the work described would not have been accomplished.

Bethlehem Diesel Engines

Bethlehem two-cycle engines of the Diesel type have been designed not only for high efficiency in operation, but for ease of inspection, disassembly and repair. These features were stressed in a moving picture exhibition in Philadelphia last fall, at the annual meeting of the Association of Iron and Steel Electrical Engineers.

In a booklet just issued by the Bethlehem Steel Company, the marine type of this engine is described in considerable detail, with a number of photographic and other illustrations, sections and assembly views, as well as clearance and dimension diagrams and installation diagrams. The engines are built with two sizes of cylinders, 26x48 in., and 27x60 in. In each size engines may be obtained with 4, 6 or 8 cylinders and the power developments run from 1,575 to 4,650 shaft hp., dependent upon the size of cylinder, number of cylinders and speed of operation.

The engine design is based on the unit system, each unit consisting of two power cylinders, together with cylinder support, A-frames, bed plate section and crank shaft section. The crank shaft sections are interchangeable, each consisting of two cranks 180 deg. apart, and with flanges on each end. Proper timing for multi-cylinder engines is obtained by bolting together the shaft sections at the desired angles.

Alan Wood Re-elects

Stockholders of the Alan Wood Iron & Steel Company, Widener Bldg., Philadelphia, have re-elected the entire board with the addition as a new member of Wm. B. Read, secretary and treasurer of the Edward G. Budd Manufacturing Company, Philadelphia. Following the stockholders' meeting, the directors elected the following officers: President, Ledyard Heckscher; vice president and treasurer, Alan D. Wood; vice president in charge of operations, H. C. Thomas; vice president in charge of sales, C. O. Hadly; secretary and assistant treasurer, John W. Logan; and assistant secretary, J. H. Woodhead.

Protective Coatings For Metals

The First of a Series of Educational Articles Dealing with Various Methods for Protecting Metal Surfaces Against Corrosion and Oxidation

By JAMES A. AUPPERLE*

GALVANIZED iron was invented almost two centuries ago, and originally consisted in first giving the metal a coating of tin and afterwards dipping the material in a bath of molten zinc (spelter). Material produced by this method was known as galvanized iron, the name has been used until very recently when manufacturers have begun to adopt the more rational term, zinc coated sheets or zinced sheets.

The zinc of commerce was originally known as spelter. This term is obsolete now and is used but rarely. The term, slab zinc, is used instead.

The slab zinc is first placed in a large pot, holding up to 80,000 lb. of zinc, then heated, using either gas or some other convenient fuel. The zinc is heated to a temperature of 850 deg. F. and maintained at this temperature with the use of pyrometers inserted in the bath of zinc. If a higher temperature is employed, the zinc coating becomes discolored and is not as durable as the zinc applied at the lower temperature. A higher temperature also produces a greater combination of iron and zinc, forming more of the iron-zinc alloy in the coating.

The slab zinc or spelter contains also some lead, iron and cadmium. Only a small percentage of the lead alloys with the zinc, the rest accumulates in the bottom of the pot. The iron in the spelter in excess of .02 per cent or .03 per cent settles as an iron-zinc alloy containing approximately 95 per cent zinc and the remainder iron. This alloy is known as dross, and floats on top of the lead in the lower portion of the pot.

Various metals are alloyed with zinc in order to obtain a more durable zinc coating. The one most commonly employed is tin. The tin content of zinc coated metals sometimes runs as high as 1 per cent, and even higher when the metal is used for special purposes. The general run of zinced sheets contain under .5 per cent of tin. This amount of tin makes the zinc much brighter and improves its adherence to the iron base.

Originally the zinc coating was applied to sheets by what is known as the hand dipped process which is somewhat slow and laborious. In this process it is impossible to control the weight of coating applied. Hand dipped sheets contain as much as 5.00 ounces per sq. ft. (2.50 ounces on each side). Such sheets, however, do not stand much forming without having the zinc coating peel.

W. T. Flanders, in his book on Galvanizing and Tinning, published by the U. P. C. Book Company, describes the hand dipped process as follows:

> "The hand galvanizing of sheet iron requires the use of a kettle long enough to accommodate the sheet and deep enough to permit of its being dipped in the bath without interfering with the dross in the bottom of the kettle; consequently, a kettle for sheets must of necessity be not less than 8 ft. 6 in. long by 4 ft. deep, and it should not be less than 18 in. in width, and a better width is 2 ft. As it is necessary to pass the sheet into the molten metal through a flux of sal ammoniac, what is known as a "flux guard" is employed. This flux guard should be made of T-iron, to which an iron plate can be riveted so that when the arrangement is placed in the bath the guard effects a longitudinal division of the metal. This flux guard should be wide enough to go under the metal 2 or 3 in. when the metal is at its lowest working height. After a sheet has become thoroughly coated it is pushed to the side of the kettle that has not been covered with a sal ammoniac flux and withdrawn from the metal with the aid of properly shaped tongs attached to a light single block and fall. If the pickling and inspection of the sheet has been properly done the coating takes place without the usual rinsing or washing in the sal ammoniac flux floating on the surface of the molten bath; but unless this has been properly done, it will be necessary to wash the sheet through the flux until a perfect coating has been obtained.
>
> "In the hand dipping method of galvanizing sheets, a simple arrangement was used that permitted the operator to transfer the sheet from the side of the kettle where it entered the bath to the opposite side where it was withdrawn, and also permitted the edge of the sheet being lifted, semiautotmatically, just high enough out of the metal to permit of its being readily seized with the tongs used for withdrawing it from the bath. It was the practice in some plants to allow the coated sheet to form spangles by cooling in the air, after which the sheet was plunged into a bath of cold water and dried off in sawdust. When it was desired to have a bright plate without the crystals the sheet was plunged into the water immediately after it had been drawn from the molten metal. This prevented the formation of crystals and, as stated, produced what was known as bright galvanized sheets.
>
> "Among the old English galvanizers it was the practice to carry a clean flux of sal ammoniac on the opposite side of the flux guard from which the sheet entered. This prevented oxidation and was the means of producing a somewhat thinner coating. It was also the practice of some operators to cover the metal on the side of the flux guard from which the sheet was drawn with foundry sand or coke dust."

In the modern plant, where sheets are coated with the use of a machine, the weight of coating is controlled very accurately, by watching the temperature of the bath, the height of the metal at the exit rolls and the speed at which the sheets are passed through the pot. The weight of coating found on zinced sheets ranges from 1.25 ounces per sq. ft. to 2.50 ounces per sq. ft.; although by a special process of zincing in which the sheets are first passed through a lead bath and finally through a thin layer of zinc, it is possible to produce sheets containing less than .75 ounce per sq. ft. In coating by the machine process, the sheets are first thoroughly pickled in sulphuric acid, rinsed in water and then placed in a weak solution of hydrochloric acid (Muriatic acid). The latter acid removes rust which may form upon the sheets, if exposed to the atmosphere for a long time after pickling and washing.

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*Middletown, Ohio.

The first rolls pass the sheets between guides, through the flux in the flux box and into the molten zinc where the guides carry the sheet to the bottom rolls which revolve in the molten zinc. From these the sheet passes between guides to the exit rolls. The exit rolls are half-way submerged in the molten zinc. The sheets passing through them always emerge from bright zinc metal and do not come in contact with the melted flux surrounding the rolls. The flux at the entrance end of the pot is about 3 in. deep and is contained in a rectangular box without a bottom. The sides of the box dip into the molten zinc about 2 in. This flux consists essentially of zinc chloride and ammonium chloride and is maintained in a liquid condition by the addition from time to time of ammonium chloride (sal ammoniac) and caused to foam by the addition of very small amounts of bran and tallow.

The sheets as they emerge from the bath of zinc take on a characteristic spangle as the zinc freezes on the metal. The sheets are then leveled, cooled and inspected; prime sheets being placed on one pile and defective sheets on another pile.

In a well maintained plant, inspectors or coating checkers are employed whose duty it is to check the weight of coating upon the sheets being coated by weighing sheets before coating and again after coating; thus determining the actual amount of zinc coating. Vigilant checking of this kind makes it possible to keep the coating within the weight range specified.

A small amount of aluminum, less than .01 per cent, one lb. to 10,000, is sufficient to materially affect the zinc coating, rendering it bright and more adherent. The use of aluminum or alloys containing aluminum is usually confined to the hand dipped process. It is impossible to use aluminum in the machine dipped process on account of the formation of a clay-like substance as a reaction product from the aluminum and oxygen. This substance sticks to the exit rolls and causes defective coatings.

Zinc is an extremely durable metal when exposed to severe service conditions. Zinced iron sheets which had been exposed for about half a century to the very corrosive atmosphere of the Panama Canal Zone have been examined and found by analysis to still contain a very heavy weight of coating. These sheets were evidently produced by the hand dipped process.

The Bureau of Standards Circular No. 80, entitled, "Protective Metallic Coatings, For the Rust Proofing of Iron and Steel" contains information in reference to preservative coatings. This states that of the metallic coatings, zinc is by far the best for general rust proofing. The principle reason for this lies in the chemical nature of zinc. It is the only one of the commonly used metals that is electro-positive to iron! that is, it has a greater tendency to become oxidized than iron.

When any steel article with a metallic coating is scratched or abraded so that a small area of the steel is exposed, the two dissimilar metals, together with a small amount of moisture from the atmosphere will form a tiny galvanic cell, set up a current, and start corrosion. That metal which is electro-positive to the other will be the one to be oxidized, while the electro-negative metal will remain uncorroded. Therefore, if the coating metal is zinc, it is zinc that will be oxidized, while the iron remains bright and uncorroded until the bare spot becomes so large that the central portion is beyond the protective zone of the surrounding zinc.

Zinc Plating.

Articles electro-plated with zinc are very durable from a corrosion standpoint; the reason being that such articles are free from iron-zinc alloys found in coatings produced by the hot dipped process. W. T. Flanders in his book on Galvanizing and Tinning, refers to this method of coating iron and steel as follows:

> "It is only within the past decade that any marked advance in the commercial use of electro-deposited zinc has been noted, and it is in the Uinted States that the deposition of this metal, by means of a low tension current, has reached its high commercial development. While the knowledge that zinc could be readily deposited has existed for a long number of years, the process was never taken up in a practical commercial way until about 1900. At that time attention was directed to the subject through experiments made by the governments of England, Germany and United States, which demonstrated the efficiency of the electro deposit for certain classes of work. In line with the experiments which had been made, the United States Government established tests and installed small electro-galvanizing plants at various arsenals and shipyards throughout the country. Manufacturers of electro-plating materials availed themselves of the information brought to their attention, and during the past 10 or 12 years the growth of this industry has been rapid and electro-zincing or galvanizing is now being applied to many iron and steel articles which could not as readily be treated in any other way."

The scope of this article does not permit of extended discussion of the solution used in this process. The solutions ordinarily used are zinc sulphate containing a small amount of free acid, or zinc cyanide, or a mixture of zinc oxide, sodium cyanide and sodium hydroxide.

A minute quantity of gelatin or colloidal matter in the electrolyte prevents adhesion of the hydrogen bubbles and facilitates the production of a smooth deposit of zinc.

The Bureau of Standards has investigated plated zinc coatings and from Bulletin No. 80, we quote as follows:

> "The principal point of interest in connection with the microstructure of this type of coating is

the variation of thickness which may exist on irregularly shaped pieces or even on flat pieces. Such variations are to be found, particularly in depressions and on sharp projections where the differences in the current density are considerable. This is especially true for the threaded portion of bolts and screws. Even on flat surfaces the coating is not of uniform thickness."

Many mechanical devices are used in zincing by the electro-plating process. Articles are carried by means of chain conveyors through the electrolyte. The chain conveyors run in a perpendicular position so that as soon as one article is thoroughly plated, another one is suspended on the same hook. Plating barrels are used in which small articles are coated with zinc. These barrels or drums are mounted on a shaft and revolve in the plating solution, thus constantly exposing new surfaces and making efficient contact with the cathode members.

The weight of zinc coating on zinc plated articles is usually under .2 of an ounce per sq. ft. of actual surface. This would be equivalent to .4 of an ounce of coating as expressed on sheet surfaces. Rivets which have been electro-plated with zinc have found a large use in the culvert industry as it was found that the upset rivets with hot dipped or sherardized coatings would crumble and flake off while the electro-plated zinc remained attached to the upset metal.

Low Temperature Carbonization of Coal[*]

Consideration of Different Processes Operated in Direct Conjunction with Steam Boiler, General Furnace and Power Plant

By DAVID BROWNLIE[†]

THE contribution is of great length, over 30,000 words, and includes 14 illustrations, while the author, who summarized the paper in about 50 minutes, showed over 60 specially prepared lantern slides, including many photographs of the plant described. He gives it as his opinion that the next stage of evolution in steam power operation is the combination of low temperature carbonization of raw coal with separation of the tar or crude oils and, if necessary, ammonia, and the combustion under the steam boilers of the residual gas, along with the smokeless low temperature fuel, either in a pulverized condition or in the solid form using traveling grate stokers. He stated that it is impossible, for example, to go on burning 8,000,000 tons of raw coal per annum under the power station boilers of Great Britain. If carbonization as part of the boiler plant operation was adopted this would give every year about 20,000,000 gallons of motor spirit, 120,000,000 gallons of low temperature tar, and 53,000 tons of sulphate of ammonia, while requiring 9,600,000 tons of coal instead of of 8,000,000 tons for the same steam output. Many super-power stations today are burning 1,000 tons of raw coal per 24 hours, and it is not much of a step to carbonize this coal, which already has to be crushed, conveyed and stored in overhead bunkers. The same applies to other chemical industries, and the author most strongly urges the colliery industry in Great Britain to co-operate together and study on scientific and practice lines the whole subject of low temperature carbonization, over 100 processes being available, as in many cases smokeless fuel and by-products could be sold to much better advantage instead of raw coal, while low grade refuse fuels also are available for utilization.

The paper is divided into the following parts and is claimed to give for the first time a comprehensive survey of this particular section of low temperature carbonization:

1—The pre-drying of raw fuels before combustion, carbonization, or gasification.

2—Low temperature carbonization, in conjunction with mechanical fixed furnaces.
  - (a) Advantages and disadvantages of the general principle.
  - (b) The "Julius Pintsch" process (of Berlin), using part of the furnace gases as the internal heating medium.
  - (c) The work of Messrs. Merz and McLellan, Ltd. (of London and Newcastle, using superheated steam as an internal heating medium.)
  - (d) The "Pluto Stoker" process (of Holland, also using superheated steam as an internal heating medium.)
  - (e) "Carbocite Dual Carbonization" or "Wisner" process (Canton, Ohio, using rotary retorts with oxidation of the charge.)

3—Low temperature carbonization in conjunction with pulverized fuel firing.
  - (a) Advantages and disadvantages of the general principle.
  - (b) The history of the carbonization of pulverized fuel.
  - (c) The "McEwen-Runge" process (London and U. S. A.)

4—The "Midland Coal Products" process (Nottingham).

5—"Staveley Coal and Iron" or "Markham" processes (Staveley, near Chesterfield).

Each of the above processes, together with much historical matter, was described at great length, giving in many cases information and data not hitherto published. In the Julius Pintsch process of Berlin, for example, in connection with which nine plants are operating in Germany, Upper Silesia, and Norway, the coal is carbonized at 1000-1250 deg. F. in front of water tube boilers, passing down continuously to the mechanical stoker hopper, by means of 35,000-45,000 cubic feet of furnace gas per ton, taken from over the top of the stoker, the total duration of the heating

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[*] Abstract of paper read before the Institution of Mining Engineers (Midland Counties Institution Section), February 17, 1926, at the University College, Nottingham.

[†] London, Eng.

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being about 6 hours. The solid smokeless fuel is then burnt on the stoker, along with the gas over the top of the fires, giving per ton a yield of 16-20 gallons of low temperture tar, 40,000 cubic feet of low grade gas 110 Btu. per cubic foot, and 1568 lbs. of smokeless fuel (70 per cent).

In the new "Wisner" process the crushed coal is first "thermodized" in a long horizontal rotary externally heated retort at about 500-600 deg. F., while a current of heated air is passed through the charge, 2,000-10,000 cubic feet per ton, the temperature being adjusted exactly so that the viscous stage is not reached. This heated oxidized coal is now carbonized at once in an adjoining rotary retort at not over 900 deg. F., and it appears to be a new discovery, contrary to the general opinion, that coal treated in this way with air in the heated condition does not lose its coking properties. For furnace work the final smokeless fuel is passed direct to the mechanical stoker hopper, and it is claimed the process is of equal value for coke oven operation, about 40 minutes "thermodizing" giving a state of advancement of the charge corresponding to 8-10 hours in a coke oven without affecting the quality of the coke.

The author gives the results of his researches into the history of the carbonization of pulverized coal and shows that the real pioneer in this field, as in that of pulverized fuel firing, is Thomas Russell Crampton of London, whose British patent for carbonizing pulverized coal is No. 2262/1872, to which detailed reference was made along with the life and work of Crampton. Also there was described the investigations of H. C. Bull (1883), J. A. Yeadon and T. Whittaker (1889-1895), Professor Vivian B. Lewes, A. Pinet and A. Debout, and Harry A. Kuhn.

The new "McEwen-Runge" process for the low temperature carbonization of pulverized coal in front of water tube boiler and other furnaces is the invention of S. McEwen of London, who commenced work on the subject in 1919. Subsequently the investigations were continued in the United States under the superintendence of Dr. Runge, a large scale experimental retort being erected at the Lakeside power station, Milwaukee, in 1923. The problems are stated to have been solved and an extensive plant, with a capacity of 200 tons of coal per 24 hours, is now being completed at Milwaukee, sufficient to operate 25 per cent of the station. In the "McEwen-Runge" process the pulverized coal, instead of being burnt in the raw state, is dropped down two vertical retorts in series externally heated, each of which gives a carbonization of 35 seconds. In the first or preheating retort the temperature averages 600 deg. F. and in the second 1050 deg. F., the volatile content of the coal being reduced to about 10 per cent by only 70 seconds carbonization because of the fine state of division. The residual fuel then passes direct to the burners, while 18-20 gallons of low temperature tar per ton is recovered, along with two gallons of motor spirit scrubbed from the mixed gas, which is 7,000-7,800 cubic feet at 400 Btu.

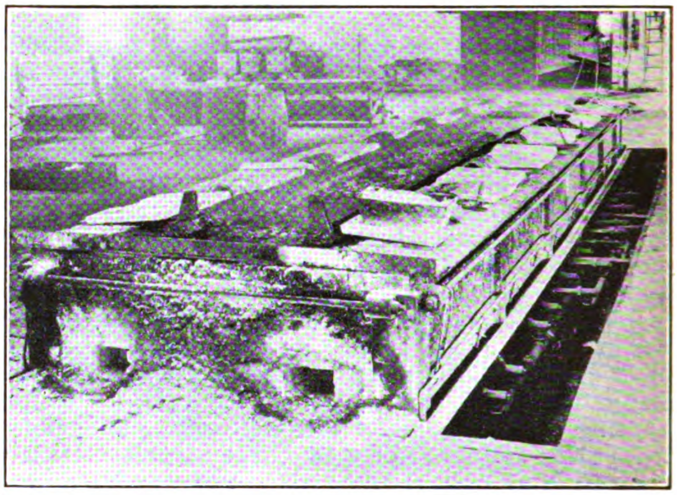
The work of the Midland Coal Products Company, Ltd., of Nottingham, associated with the well-known Butterley Company, Ltd., of Derby, is of the greatest interest in connection with the utilization of small non-coking slacks, and the same applies to that of the Staveley Coal & Iron Company, Ltd., using cannelloid colliery refuse such as "bats," "jacks," "black shale" and similar products. A detailed description of this work is given for the first time, including the experiments now being carried out to use the exhaust of a huge 7,150-hp. gas engine, operating on blast furnace gas, for carbonization, passed direct through the charge in a vertical intermittent retort.

Gas Fired Galvanizing Kettle

By F. X. Mettenet*

The galvanizing process described in this article is the one in which the "hot" method is used. This installation has been in service for 18 months and is giving very satisfactory service with coke oven gas of 530 Btu. and .38 specific gravity.

In preparing the iron or steel articles for galvanizing they are first cleaned or pickled in an acid solution to remove all foreign matter, leaving a clean surface for the metal protective coating. They are then dipped into the hot metal solution, after which the excess metal is rapped off, and immediately submerged in water which has the effect of setting the coating in a uniformally distributed condition.



It has been found that gas is ideal for this class of work due to the fact that the distribution of heat is maintained within very close limits during working hours, also over holidays, week ends and night periods, at which times it is desired to keep the bath just above the freezing point. The savings in labor and fuel alone on this installation are large factors contributing to the successful use of gas heat.

The kettle is 25 ft. 4 in. long, 1 ft. 10 in. wide and 2 ft. 10 in. deep; when filled to within 6 in. of the top it holds 48,000 lbs. of zinc spelter. It is heated with 42 gas burners equally spaced along each side. The fuel is projected into a bed of refractory material which has a double value of equally distributing the heat by radiation and preventing spot heating. It has been found that fuel when projected against the sides of a kettle has the effect of rapidly oxidizing or scaling that portion and greatly reducing its useful life. Automatic gas control is used when operating on ordinary production and on holding periods. Extra burners are provided for heavy production periods. The gas pressure varies from 2 to 10 lbs. per sq. in. according to requirements. Atmospheric air is pro-

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*Northern Indiana Gas & Electric Co., Hammond, Ind.

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vided by inspiration in quantities sufficient for complete combustion, thus eliminating the necessity of a blower for this purpose. The desired temperature, within 5 deg. F. plus or minus, is maintained at all times. The maximum and minimum gas consumptions are 4,400 and 350 cu. ft. per hour respectively.

The data assembled from actual operations on this installation during the first 11 months shows that 2761 tons of material was galvanized with a gas consumption of 9,181,600 cu. ft. of gas, or 1.66 cu. ft. of gas per lb. of metal. This gas consumption also includes that used for heating a small plant office.

The Bates Company was not an exception to the rule when approached on the subject of using gas on their galvanizing kettle, that is, they were very skeptical as to the cost of gas per unit of finished product compared with other fuels, furthermore they could not be convinced of the many possible miscellaneous savings and improved quality of product. Arguments brought to bear in favor of gas led them finally to "take a chance" for which they are very much pleased today and are classed among the many boosters for industrial gas.

The advantages gained by the use of gas plus the automatic temperature control on this class of work are many. Some that might be mentioned are, minimum labor, accurate temperature control, uniform metal coating, no attention when not in use, no danger of bath freezing, no extra drossing from overheating, no loss of time in mornings or during the day as in the use of coke, life of kettle two to three years as compared with six months when using coke and no spot heating on kettle. These savings while being difficult to estimate in dollars and cents, are nevertheless of vital importance in the operation of a galvanizing plant.

A. S. T. M. Announces Convention Program

The Twenty-ninth Annual Meeting of the American Society for Testing Materials, will be held at the Chalfonte-Haddon Hall, Atlantic City, N. J., June 21-25. No general sessions have been arranged for Monday, this day having been reserved for committee meetings and for registration. The first session will be held on Tuesday afternoon, at 2 o'clock, and the President's Address on Tuesday evening. As in the past, simultaneous sessions on a number of occasions will be necessary, but the opening and closing session and one general session devoted to testing and the Presidential Address, will be single sessions. In addition, one session devoted exclusively to the delivery of the first Edgar Marburg Lecture has been arranged for Wednesday afternoon, at 4 o'clock. In all, thirteen sessions will be held, each of them replete with interesting and valuable reports and papers. On Thursday evening three sessions will be held concurrently but the subjects to which these sessions are devoted are such that there will be scarcely any conflict.

Program of the Meeting.

Valuable papers are being presented on the testing of cast-iron pipe. Corrosion again will receive considerable attention and one session has been devoted to the discussion of this subject, together with fatigue of metals. The effect of high temperatures upon the properties of metals is treated in two papers as well as in the Report of Committee A-1 on Steel. An outstanding topic is the magnetic testing of steel, an important contribution in this field of investigaton being made by Committee A-8 on Magnetic Analysis. A series of interesting and valuable papers are included on concrete and on instruments of testing. Committee E-1 is presenting very interesting reports on the preparation of methods of testing as applied to a number of materials, including the testing of thin sheet metals.

Entertainment Features.

Wednesday evening will be reserved exclusively for the A.S.T.M. informal dance and smoker and perhaps other entertainment. Friday afternoon will be devoted to recreation, the annual golf and tennis tournaments being held at this time. The committee will probably arrange for a lecture on Thursday afternoon since these lectures have been quite popular in the past. More complete information with regard to the above and additional entertainment features will be made in a circular to members and at the annual meeting. Every effort will be made to provide appropriate entertainment features both for our members and the ladies accompanying them.

Summary of Program.

MONDAY, JUNE 21

2:00 P. M.—Opening of Registration.
Afternoon and Evening—Committee Meetings.

TUESDAY, JUNE 22

Morning—Committee Meetings.
2:00 P. M.—First Session: Wrought Iron, Cast Iron and Magnetic Testing.
8:00 P. M.—Second Session: Presidential Address, Reports of Administrative Committees and Testing.

WEDNESDAY, JUNE 23

9:30 A. M.—Third Session: Steel. Fourth Session: Brick, Tile, Refractories and Fire Tests.
2:00 to 4.00 P. M.—Recreation and Committee Meetings.
4:00 P. M.—Fifth Session: Edgar Marburg Lecture.
9:00 P. M. —Informal Dance and Smoker.

THURSDAY, JUNE 24

9:30 A. M.—Sixth Session: Corrosion and Fatigue of Metals. Seventh Session: Road Materials, Waterproofing, Petroleum Products and Thermometers.
Afternoon—Recreation and Committee Meetings.
8:00 P. M.—Eighth Session: Non-Ferrous Metals and Metallography. Ninth Session: Textiles, Rubber, Coal, Timber, Insulating Materials and Slate. Tenth Session: Symposium on Rosin.

FRIDAY, JUNE 25

9:30 A. M.—Eleventh Session: Preservative Coatings and Naval Stores. Twelfth Session: Cement, Lime, Gypsum and Nomenclature.
Afternoon—Recreation.
1:00—Golf and Tennis Tournaments.
8:00 P. M.—Thirteenth Session: Concrete.

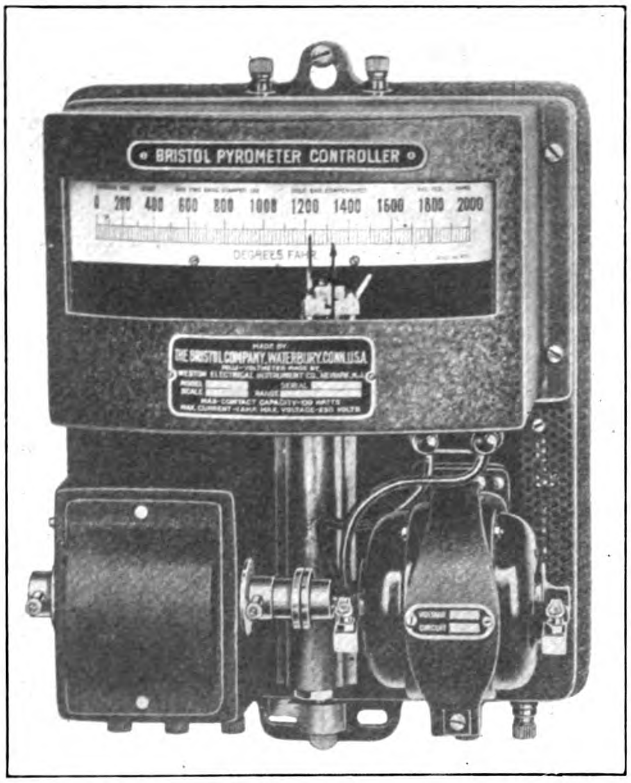
Hours given are Daylight Saving Time.

NEW EQUIPMENT SECTION

Bristol Pyrometer Controller

A new Bristol Pyrometer Controller Model 479 has been developed which is the result of four years experimental work and trial under actual operating conditions in the field. It includes the recent improvements found in other types of Bristol's Pyrometer Equipment and many additional features.

An extra wide scale, 7-in. in actual measurement, is an important feature of this new controller.


BRISTOL PYROMETER CONTROLLER
0 200 400 600 800 1000 1200 1400 1600 1800 2000
DEGREES FAHR.
THE BRISTOL COMPANY, WATERBURY, CONN. U.S.A.

Bristol pyrometer controller.

The governor used to regulate the speed of the driving motor is reliable and positive in its operation. All parts of the governor mechanism and gears are accurately aligned and doweled to maintain permanent adjustment. The motor, with horizontal axis, is connected to the driving shaft by means of a non-metallic coupling which reduces friction and noise.

The mechanism which transmits power from the cam to the switch, is accurately set up and adjusted with set screws. To insure against slipping or any possible change in adjustment, every joint is pinned.

The plane of travel for the switch is fixed, and so designed to be horizontal when installed for operation; other parts are carefully adjusted with this as a reference plane. The millivoltmeter movement is accurately adjusted, so that the pointer swings in a plane parallel to the plane of motion of the switch. As a result of this relative adjustment, the switch operates with certainty at any part of the scale arc.

After the pointer has been aligned to follow the proper path, the anvil or plate against which the pointer tip, or steeple, is pressed, is adjusted so that the steeple on the pointer will always have sufficient clearance from the plate; but will still move a minimum distance when the switch is brought up against it.

The steeple which takes the pressure when the switch is brought up, is in effect, a small inverted wedge, the base of which is brought to rest on the anvil plate. The apex of this wedge is in contact with the small button which throws the switch over. It is apparent that the pressure on the steeple, is all absorbed by the plate against which it is pressed. There can be no lateral thrust on the pointer, and no force along the pointer arm towards the pivots. The above method of construction and the very short distance which the steeple actually travels, reduce the pressure applied to the pivots, to an almost negligible amount.

The complete moving mechanism which supports the switch is assembled in one unit, which unit is supported rigidly in a bearing having a total area of about 4.5 sq. in. and is 6-in. long.

Also, there can be no play in the vertical motion of the switch, for the following reason. The switch-supporting mechanism is continuously held up against the depressor arm by a stiff spring, which supplies the power to raise the switch. The motor-driven cam forces the depressor arm down against the center shaft of the switch-supporting mechanism, which lowers the switch; the spring forcing it up when the depressor arm is raised.

An improvement in the construction of this controller, is the safety adjusting mechanism, for setting the position of the index at the point to which it is desired to bring the temperature. A small hinged cover encloses the adjusting knob. This knob cannot be operated until the cover is opened; and the act of opening the cover automatically forces the switch mechanism to its lowest position, where it is entirely free from the pointer. With this provision there is no possibility for the operator to damage the millivoltmeter movement by attempting to set the index at the instant when the switch is in contact with the pointer steeple.

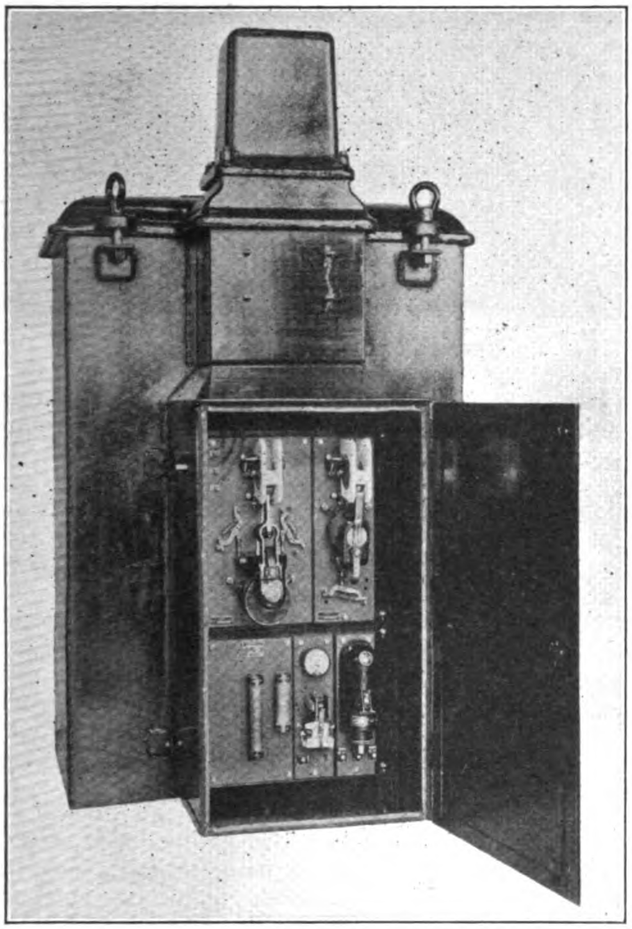
The top of each of the small buttons against which the steeple rests when the switch is making contact, is a circle of about ¼-in. diameter. If the pointer is near the desired temperature, whether contact is made on the high or low side is decided by a sharp knife-edge. The knife-edge is in axial line with the index, and situated midway between the two buttons which operate the switch. The pointer is depressed on either side of the knife-edge and there can be no neutral position. After being guided to one side or other by the knife-edge, the steeple operates against the top of the button, which has sufficient area to make positive operation, and throws the switch to the maximum or minimum position.

Synchronous Motor Control

A completely self contained, oil-immersed Automatic Starter for 2,300-volt Synchronous Motors has been developed by the Electric Controller & Manufacturing Company, Cleveland, Ohio.

This is built for across-the-line starting of slow speed motors, and for reduced voltage starting of the higher speed motors. The full voltage equipment for starting slow speed motors is of similar appearance except that the height is reduced. In each case the operator simply pushes a button to start the motor and as the motor approaches sychronous speed, the field excitation is automatically applied.

The reduced voltage starter consists of a welded boiler-plate tank which contains an automatic double-throw switching mechanism, a power transformer for providing starting voltage, potential transformers for providing 280-volts for the Master Switch operating current and the current limit transition relay, which connects the motor to full voltage when it has been accelerated to approximately 85 per cent of synchronous speed.



Reduced voltage starter.

On the outside of the tank there is a dustproof steel cabinet which encloses a field switching mechanism, field discharge resistor, timing relay and d.c. field ammeter. This cabinet may also contain an automatic starter for operating a magnetic clutch. The full voltage starter is of similar construction except that the starting auto-transformers are omitted. This equipment is complete in a single unit.

New Northern Electric Hoist

The Northern Engineering Works, Detroit, Mich., has brought out a new type of electric hoist which is now ready for the market, known as the Northern Standart-ized Hi-Lift. The new hoist is essentially the same design as their type "LE" crane trolley. All of the features of this crane trolley have been employed in the new hoist.

Northern Hi-Lift electric hoist.

The hoist is now in production and is described in their bulletin EH-101. The design embodies the high hook lift feature requiring only a minimum of head room and makng it available for service in places of limited height. Among some of the outstanding features are hammered steel case hardened gearing, entirely enclosed and running in lubricant, Timken bearings throughout, exceptionally large hoisting drum and rope sheaves insuring long life and protection for the steel wire hoisting rope, the application of any standard make of motor designed for hoisting service.

Safety features include the enclosing of all working parts, two brakes for holding and controlling the load, and a double set of automatic limit stops that not only limit the upward movement of the load hook, but interrupt the downward movement at the proper distance, thereby preventing injury and difficulties that often occur through allowing the entire length of hoisting rope to unwind and reverse.

Book Review

Metal Statistics. Published by the American Metal Market. Price $1.00, postpaid. The 1926 edition of "Metal Statistics" is larger than any of the preceding issues, and contains the most complete record published of statistics on practically every phase of the iron, steel and metal industries.

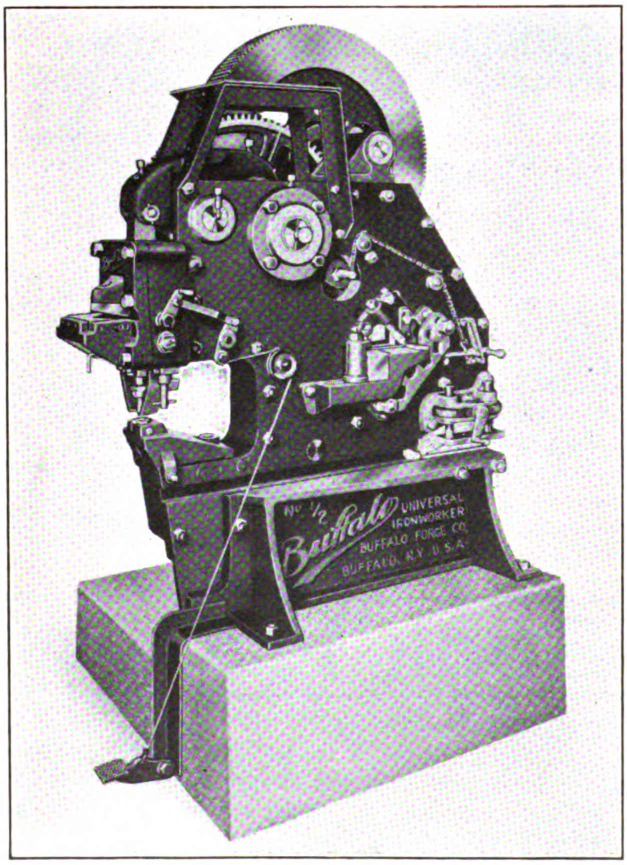
The usual tables of production, consumption, imports, exports, stocks, prices, averages, etc., have been entirely revised and include the latest available data for 1926. In addition, many new tables have been added, not only on iron, steel and metals and their allied products, but also on subjects of general interest of such importance as to greatly enhance the value and usefulness of the book as a complete, authoritative statistical reference work for the iron, steel and metal industries.

New Buffalo Iron Worker with Coper

An addition to the line of punches, shears and bar-cutters manufactured by the Buffalo Forge Company, of Buffalo, N. Y., is the new No. ½ Universal Iron Worker, with built-in Coper. In shops where much coping work is done on angles, I-beams, tees, channels, zees, plates and flats, as well as other rolled shapes, the new machine will be particularly useful, as in addition to the coper, it has regular punch, shear and bar cutter of the Universal Iron Worker.

The coper is built on the punch end of the machine, as shown in the illustration, being operated by the same plunger, and actuated by the same controls, either hand or foot. The foot control enables the operator to handle all kinds of punching and coping work without delay and also makes it possible to operate the machine with both hands on the work.

The specific advantage of the built-in coper is the fact that it is not necessary to interchange the coping tools with the standard punching tools, as required with the ordinary coping attachment. The coper, as described here, can also be supplied with other Buffalo Armor Plate punches. A sheet steel cover guard, not shown in the illustration, is provided to fit over the coper to protect the operator.



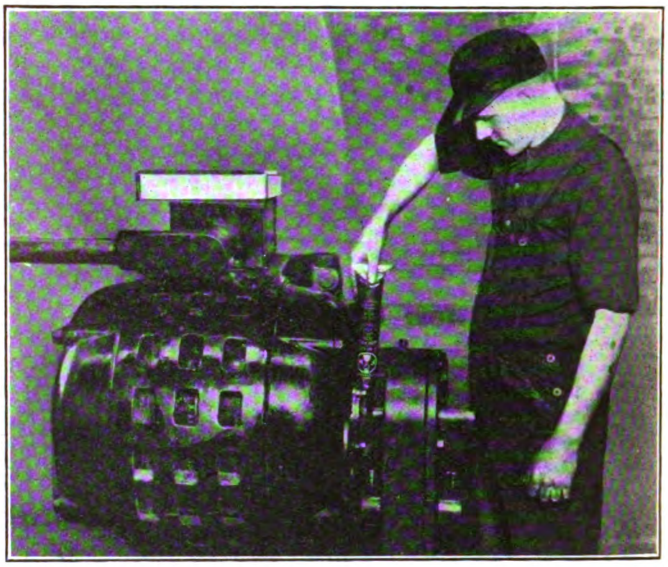
Iron worker with coper.

The built-in coper has an extremely large capacity. The No. ½ Iron Worker coper will handle 5-in. channels, 6-in. beams and 3 x 3 x 5/16-in. angles. No. 1½ takes 6-in. channels, 7-in. beams and 3 x 3 x ⅜-in. angles. One cut only is required for full depth on all sections.

Since the construction of this coper required redesigning the punch end of the Iron Worker, it cannot be supplied for machines now in use. In the new machine, all steel castings are used, making a very strong and reliable construction.

Grease-Tube Method Solves Lubrication

Proper lubrication of motors was always a vexatious problem until it was greatly simplified through the advent of the ball-bearing motor with its inherent low bearing friction. Fairbanks, Morse & Company, of Chicago, have introduced an improvement that simplifies motor lubrication by furnishing the proper grade of grease in collapsible tubes, each containing just enough grease for a motor's annual requirements. After flushing out the old grease with kerosene, the new grease is squeezed from the grease tube directly into the bearing. The directions show just how much to put into each bearing for the best results. Four sizes of tubes are available for corresponding sizes of bearings.



Grease tube for motor lubrication.

There are many advantages in this tube method of greasing. The kind of grease best adapted for ball-bearing is used. It is of the proper adhesiveness to cling to the balls, it maintains its consistency through all normal temperatures without being too stiff when starting in the cold, or melting and flowing out of the bearing when running at full load.

It is free from gritty or corrosive constituents. No dirt or other deleterious matter is introduced into the bearing. The likelihood of using a stick or other random object of questionable cleanliness of taking grease from an open can to the bearing is entirely eliminated. The cap of the housing is not removed, only the plug. No grease is wasted or smeared outside of the housing and no wiping is needed. Just the right amount of grease required for the most perfect lubrication is used in each bearing.

New Blast Furnace Blown In

The Inland Steel Company at its Indiana Harbor works erected a new blast furnace stack, rated at 700 tons, which will bring the daily pig iron capacity to 2,375 tons. The blast furnace stack was put in operation May 4th by Mrs. H. H. Straus, daughter of P. H. Block, president of the company.

PERSONALS

Theodore H. Harvey, vice president, Ohio Steel Foundry Company, has been appointed general sales manager, covering both the Springfield and Lima plants of the company.

* * *

Harry Heffrin, formerly of the Kittanning Iron & Steel Company, Kittanning, Pa., has been appointed blast furnace superintendent in charge of operations of the top furnace department of the Wheeling Steel Corporation, Wheeling, W. Va. He succeeds W. J. Huge, who resigned.

* * *

O. C. Sheldon, formerly advertising manager, Riley Stoker Corporation, Worcester, Mass., has been transferred to the Cincinnati office of that company as district manager.

* * *

R. H. Stuhler, formerly general superintendent, McKeesport Tin Plate Company, has resigned after eight years of service.

* * *

T. H. Rogers, formerly general superintendent of the Follansbee Brothers Company, West Virginia plant, is now associated with the Weirton Steel Company, in the automobile sheet division.

* * *

John Fielding, Jr., has been appointed purchasing agent, McKinney Steel Company, Cleveland. He has been associated with the company seven years, and previous to his promotion was assistant to Donald B. Gillies, vice president in charge of mines, with headquarters in Cleveland.

* * *

T. L. Clossen, formerly in charge of the Empire Rolling Mill Company, Cleveland, has been appointed district sales manager for Ohio for the Seneca Iron & Steel Company, Buffalo, which has established an office at 915 Guarantee Title Bldg., Cleveland.

* * *

J. B. Chalmers, formerly employed by the American Sheet & Tin Plate Company, Gary, Ind., has recently been made superintendent of the new tin mills of the Youngstown Sheet & Tube Company, Indiana Harbor, Ind.

* * *

D. R. Mathias, general superintendent of the Joliet Works of the Illinois Steel Company, has returned from a 10-week trip to the Mediterranean.

* * *

Willard S. Haring has been appointed general manager of sales for the Alan Wood Iron & Steel Company, Philadelphia. He had been assistant general sales manager and had been connected with the Alan Wood Company for 20 years.

* * *

F. H. Moyer has resigned as general superintendent of the United Alloy Steel Corporation, Canton, Ohio, effective April 30. He will establish a private business as consulting and development engineer.

J. M. Duncan, for 14 years Pittsburgh district manager for the Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa., has been promoted to assistant general sales manager of the company.

* * *

J. Frederic Wiese has been appointed purchasing agent of the Parkesburg Iron Company, Parkesburg, Pa., succeeding his father, the late H. B. Wiese.

* * *

Frederick B. Huffnagel was elected president of the Crucible Steel Company of America at a directors' meeting held in New York. He succeeds E. C. Collins, recently resigned.

* * *

Emil Gathmann was elected president of the Gathmann Engineering Company, metallurgical engineers and makers of ingot molds, Baltimore, at a meeting of the company's directors held April 19.

* * *

Ross Huntington McMaster was recently elected president of the Steel Company of Canada, Ltd., Hamilton, Ont.

OBITUARIES

Major Albert F. Walker, for many years sales agent in Boston for the American Steel & Wire Company of Worcester, Mass., died in Boston on April 22. He was 54 years old.

* * *

John Mulligan, aged 55, president of the Ulster Iron Works, Dover, N. J., died May 6, at Clifton, N. Y.

* * *

Victor Angerer, first vice-president and a director of the Taylor-Wharton Iron & Steel Company, High Bridge, N. J., died May 5 at his home in Ridley Park, Pa. Mr. Angerer was born in Austria, June 4, 1861.

* * *

R. Sanford Riley, internationally prominent combustion engineer, died at his home in Worcester, Mass., May 7, aged 51.

* * *

Leonidas Merritt, discoverer of the first iron ore at the western end of the Mesabi range, died in Duluth, May 9, aged 82.

* * *

Franz Roessler, chairman of the board of the Roessler & Hasslacher Chemical Company, New York, and, with the late Jacob Hasslacher, a founder of the company, died March 24. The company was founded in 1885.

* * *

David M. Dillon, one of the first manufacturers to construct steam boilers of steel, died at Fitchburg, Mass., April 28 at the age of 83.

* * *

W. B. Laufman, active in the sheet and tin plate business until the company in which he was interested was absorbed by the American Sheet Steel Company, 25 years ago, died at his home in Pittsburgh, April 28. He was born in Pittsburgh 77 years ago.

TRADE NOTES

Several new cranes of large capacity are being erected in the plant of The Ludlum Steel Company, Watervliet, N. Y., manufacturers of carbon and alloy tool steels. These cranes are being installed for handling the outside storage of raw material for their melting furnaces.

* * *

The Northern Engineering Works, Detroit, Mich. has appointed Mr. W. Scott Thomas, 315 National Exchange Bank Building, Providence, R. I., as a special foundry equipment sales representative in the New England section. Mr. Thomas, who has been connected with the J. W. Paxon Company as manager of their New England business, has had extensive experience in the foundry equipment line. He will handle the Northern "Newten" cupola, electric hoists and air hoists, as well as the other material handling products manufactured by the Northern Engineering Works.

* * *

Elyria Iron & Steel Company has bought the business and plant of the Superior Metal Products Company, both companies of Elyria, Ohio. Hugh B. Wick is president of both. The Superior company manufactures metal stampings.

* * *

M. A. Hanna Company, Cleveland, has moved its office in Detroit to 1426 Buhl Building.

* * *

W. C. Frye and C. R. Messinger of Milwaukee, and W. J. Nugent of Chicago have purchased the interests of Charles Piez, chairman of Link-Belt Company and Prentiss Coonley, of the Walworth Company, Milwaukee. Mr. Frye and Mr. Messinger, with Mr. Piez and Mr. Coonley were the principal organizers of the Nugent Company.

* * *

General Motors Corporation has bought a tract of 160 acres South of Detroit on the Grand Trunk Railroad, which is said in the absence of official announcement, to be destined for a plant for the Yellow Truck & Coach Mfg. Company, the Chicago plant of which is said to be of insufficient capacity.

* * *

Hartford Foundry Corporation has started operations in the former plant of the National Machinery Company, Wethersfield, Conn. Edgar Spencer, formerly superintendent of the Connecticut Foundries at Rocky Hill, Conn., heads the new company.

* * *

F. J. Ryan & Company, Philadelphia, has let contracts for office building and shop at Hunting Park and Wissahickon Avenues, providing more than five times present space for construction and testing of burners, and automatic combustion and temperature control devices. Certain standard furnace equipment coming within shipping limits, also will be tested.

* * *

The Halcomb Steel Company, Syracuse, N. Y., announces the removal of its New York office and warehouse from 401 Canal Street to Clarke and Dominick Streets.

Hickman, Williams & Company, Inc., dealers in pig iron, coke and scrap, have moved their New York office from 1548 Equitable Building to room 1441 in the same building.

* * *

Harbison-Walker Sales Company, has established a direct branch at 28 South Canal Street, Milwaukee, in charge of H. T. Lewis, who has represented the company for several years.

* * *

A new skelp mill for installation at the Benwood division of the Wheeling Steel Corporation has been authorized by the directors. This division at present includes a 24-inch, 3-high, 2-stand unit with an annual capacity of 30,000 tons of skelp. The added capacity will be absorbed by the Benwood tube department of the company.

* * *

Century Electric Company, St. Louis, which recently took out permits for factory buildings, does not plan to start operations until fall. Later a large factory group will be erected to give enlarged production.

* * *

Oklahoma Steel Casting Company, Tulsa, Okla., has bought a 10-acre site at Houston, Tex., on which it will build a foundry plant at once. The Tulsa foundry has a capacity of 400 tons per month. The first unit of the plant at Houston will have a capacity of 300 tons per month. Ernest H. Cornelius is president.

* * *

Central Iron & Steel Company, Harrisburg, Pa., has moved its New York offices from 2 Rector Street to the New York Evening Post Building, 110-116 Washington Street.

* * *

The Pennsylvania Railroad Company has arranged a tentative program for extensions and improvements in the Pittsburgh district during the remainder of the year, including additions to the boiler and plate shops of the Pitcairn, Pa. yards, primarily for locomotive boiler works, estimated to cost $60,000; new scraphandling crane at Conway, Pa.; mechanical loading station at Thomson, Pa.; development of property on Sixteenth Street, Pittsburgh, for freight house service, with complete mechanical handling and conveying equipment, and miscellaneous work. The complete program is reported to cost $13,000,000.

* * *

The S. G. Taylar Chain Company, 140 S. Dearborn Street, Chicago, manufacturer of iron and steel chains, etc., are asking bids for a one-story addition to its plant at Hammond, Ind., 60 x 100 ft.

* * *

The Morse Chain Company, Ithaca, N. Y., manufacturer of silent transmission chains and systems has awarded a general contract to Alexander, Shumway & Utz, Inc., 80 South Fitzhugh Street, Rochester, N. Y., for a five-story addition, 80 x 300 ft. to cost $125,000.

* * *

Joseph T. Ryerson & Sons, Inc., Chicago, iron and steel products, has concluded arrangements for the purchase of the reinforcing steel bar division of the Penn Metal Company, 65 Franklin Street, Boston, with plant at North Cambridge, and will consolidate with its business.

The West Penn Power Company, West Penn Building, Pittsburgh, will soon begin the construction of a power dam for hydro-electric power development on the Blackwater River, near Davis, W. Va.

* * *

The Sharon Steel Hoop Company of Sharon, Pa., has placed a contract with the Chapman-Stein Furnace Company of Mt. Vernon, Ohio to furnish the engineering, Chapman-Stein Recuperators and special furnace material for completely rebuilding one of their old type Continuous Furnaces. This was not originally a Chapman-Stein furnace. The furnace as rebuilt will have an inside width of 32 feet, an effective length of 29 feet and will have a capacity, when heating cold steel to rolling temperature, of 30 tons per hour. Producer gas will be used for fuel.

* * *

The Clinton Iron & Steel Company, West Carson Street, Pittsburgh, has applied for permission to construct and operate a coke-unloading plant on the left bank of the Monongahela River, near the Wabash Bridge.

* * *

The New Process Steel & Iron Works, Noblesville, Ind., will soon take bids for a one-story addition, 100 x 200 ft. A considerable portion of the structure will be equipped for bar storage. F. Kinnear is president.

* * *

The Ajax Electrothermic Corporation, 636 East State Street, Trenton, N. J., manufacturer of electric furnaces, alloys, etc., has work under way on its new plant at Fernwood, N. J., comprising a one-story unit, 60 x 203 ft. with two-story office building, and expects to have the plant ready for operation early in the summer. It will cost about $150,000. The company is subsidiary of the Ajax Metal Company, 46 Richmond Street, Philadelphia, Pa.

* * *

The American Rolling Mill Company, Middletown, Ohio, is said to be arranging a fund of $250,000 for additions at Ashland, Ky., where a large project will be carried out in the near future.

* * *

The Lufkin Rule Company, Saginaw, Mich., manufacturer of steel rules, tapes, etc., is having plans drawn for a two-story and basement addition to cost about $70,000, for which bids will soon be asked. Smith, Hinchman & Grylls, Marquette Building, Detroit, are architects.

* * *

The Broken Hill Proprietary Company and Rylands Brothers, Newcastle, New South Wales, Australia, affiliated, have plans under way for new works for the manufacture of wire netting and kindred wire goods.

* * *

The Canadian Furnace Company, Ltd., Port Colborne, Ontario, Canada, blew in their stack on April 16, and have it worked up to capacity of 350 tons per day.

* * *

The branch office of the Timken Roller Bearing Service and Sales Company, located at 1033 Cathedral Street, Baltimore, Md., was closed May 1. The service requirements of Timken customers in this territory will be supplied through the Richmond, Pittsburgh, and Philadelphia branches.

Republic Metalware Company, Alabama Street, Buffalo, has awarded a general contract to the Metzger Construction Company, 676 East Genessee Street, for extensions and improvements in its three-story plant, 52 x 100 ft. to cost about $100,000. Hudson & Hudson, Dun Building, are architects.

* * *

The Wellsville Foundry Corporation, Wellsville, N. Y., has been organized with capital of $20,000 to manufacture gray iron castings and the plant will be in operation about May 1. O. Delford Fedderman is president and treasurer, and J. Albert McEachern, vice-president and secretary.

* * *

The McClintic-Marshall Company, 38 South Dearborn Street, Chicago, will build a one-story brick structural fabricating shop to cost $500,000. The architect is J. W. Davis, 38 South Dearborn Street.

* * *

The Shaw-Walker Company, Muskegon, Mich., manufacturer of metal and wood filing equipment, bookcases, etc., has let contract to the O. F. Miller Company, Kalamazoo, for a five-story and basement addition, 110 x 215 ft., estimated to cost $250,000 with machinery. Albert Kahn, Inc., Marquette Building, Detroit, is architect. L. R. Walker is secretary and treasurer.

* * *

Edward G. Budd Mfg. Company, 12141 Charlevoix Avenue, manufaturer of steel automobile bodies, etc., will soon begin the erection of a one-story addition, 130 x 550 ft. to cost $400,000 with equipment. Headquarters are at Twenty-first Street and Hunting Park Avenue, Philadelphia.

COMING MEETINGS

June 1-4—Society of Automotive Engineers. Summer meeting, French Lick Springs, Ind. John Warner, manager of meetings, S. A. E., 29 West Thirty-ninth Street, New York City.

* * *

June 21-25—American Society for Testing Materials. Annual Convention at Chalfont-Haddon Hall, Atlantic City, N. J. C. L. Warwick, 1315 Spruce Street, Philadelphia, Pa., secretary.

* * *

September 1, 2 and 3—American Railway Tool Foremen's Association. Annual convention and exhibit, Hotel Sherman, Chicago. G. G. Macina, secretary, 11402 Calumet Avenue, Chicago, Ill.

* * *

September 20-24 — American Society for Steel Treating. Annual Convention and National Steel and Machine Tool Exposition at Municipal Pier, Chicago, Ill. W. H. Eisenman, 4600 Prospect Avenue, Cleveland, Ohio, secretary.

* * *

Sept. 27-Oct. 1—American Foundrymen's Association. Second international foundrymen's congress, Detroit. R. E. Kennedy, secretary, 909 W. California Street, Urbana, Ill.

TRADE PUBLICATIONS

Oxygen—The Air Reduction Sales Company, New York, in a recent bulletin emphasizes the necessity for purity of that gas in metal cutting operations and presents a facsimile of the guarantee tag on its cylinders.

* * *

Speed Reducer—The Boston Gear Works Sales Company, Norfolk Downs, Quincy, Mass., is mailing a leaflet illustrating the household use of an adjustable speed reducer.

* * *

Pneumatic Tools—The Independent Pneumatic Tool Company, Chicago, in a well illustrated catalog describes various types of pneumatic tools, such as chipping hammers, scaling hammers, riveting hammers, core busters, sand rammers, piston air drills, turbine air drills and motor hoists. Many phantom drawings showing the features of the tools are contained in the catalog.

* * *

Gears—A catalog covering its complete line of speed reduction units has been issued by the Philadelphia Gear Works, Philadelphia. It is fully illustrated and ample description is given of the devices and their parts.

* * *

Silica Sand—The Portage Silica Company, Youngstown, Ohio, is issuing a booklet showing the production of silica sand from quarry to finished product in picture form. This sand can be supplied for either molding or sandblasting.

* * *

Centrifugal Pumps—Pennsylvania Pump & Compressor Company, Easton, Pa., in a bulletin, No. 207, describes the multistage centrifugal pumps of the single-suction opposed impeller type. The bulletin is illustrated with many photographs, cross-sectional views and drawings of the various models, and the description is very full. The catalog conforms to the standards of previous bulletins issued by the company.

* * *

Material Handling—Eugene B. Clark, Clark Tructractor Company, Buchanan, Mich., has written an interesting and artistic little booklet entitled the "Clark Theory of Labor." Small cartoon cuts illustrate the booklet, which discusses the value of proper methods for material handling as a means of reducing the cost of unskilled labor.

* * *

Air Pumps—Bridgeport Brass Company, Bridgeport, Conn., describe their line of hand pumps for automobiles, motorcycles, bicycles and pressure lamps, and oil and grease guns, in a recent bulletin, No. 23.

* * *

Electric Motors—General Electric Company, Schenectady, N. Y., in Bulletins Nos. GEA-6, 71 and 246 on squirrel cage, induction and synchronous motors, respectively, shows detailed drawings and photographs, and contain brief paragraphs describing the various points of design.

Suction Pumps—Morris Machine Works, Baldwinsville, N. Y., has issued its bulletin No. 122, containing 20 8x10½-in. pages, describing the Morris double-suction pumps having horizontally split casings. The description is full and well organized. Tables show the sizes in which the pump can be had. The catalog is profusely illustrated with photographs of various construction details and of many illustrations of the pumps.

* * *

Pyrometers—The Brown Instrument Company, 4501 Wayne Avenue, Philadelphia, Pa., in a bulletin recently issued describes its various models of recording pyrometers. Illustrations are included in the circular.

* * *

Shelving—David Lupton's Sons Company, Philadelphia, Pa., in a large and well illustrated catalog, No. C-174, briefly describes the various types and views of display and storage equipment.

* * *

Welding Apparatus—Burke Electric Company, Erie, Pa., in its bulletin No. 133, arranged for loose-leaf filing, describes and illustrates the various types of electric arc-welding equipment manufactured by this company. The descriptions are quite full and show the uses and advantages of each type.

* * *

Oil Circuit Breakers—Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa., has published Special Publication No. 1643-A, describing the general application of oil circuit breakers, the determination of short-circuit current and the precautions necessary.

* * *

Drop-Forged Tools—Billings & Spencer Company, Hartford, Conn., has issued a handy guide for all in the wrench-using trades, with wrench index tables, giving dimensions of wrench openings to fit standard nut and bolt sizes. The new products are set off on colored pages.

* * *

Valves—Homestead Valve Manufacturing Company, Chicago, has published a new catalog of supplies for the foundry. The catalog is well illustrated, gives the sizes of the equipment, etc., and other information.

* * *

Hand Trucks—The Colson-Cleveland Company, Cleveland, has issued a pocket catalog of its institutional, commercial and industrial trucks, indicating a wide range of uses to which they are put, with illustrations of dozens of types.

High Speed Steel for Machine Knives

Henry Disston & Sons, Inc., Philadelphia, have adopted high-speed steel for machine knives. This steel, which combines hardness with toughness to an unusual degree, is claimed to provide a cutting edge that will retain its sharpness, and at the same time withstand hard service. This steel is also employed in the company's Lock-Weld inlaid planer knife, in which a section of the new high-speed tool steel is inlaid in a carbon steel back. The inlaid piece is of the same thickness clear to the slots, which permits the cutting face of the knife to be ground away in repeated sharpenings.

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JUN 1 7 1926

The Blast Furnace and Steel Plant

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PITTSBURGH, PA., JUNE, 1926

Entered as second class mail matter at Pittsburgh, Pa., under the act of Congress, March 3, 1879.

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In those twelve years we have installed over 640

Pokerless Producer-Gas Machines

without radical change of design and they still stand preeminent above all competition in that almost priceless quality, RELIABILITY.

There have been continuous improvements (as for example our highly efficient noiseless steam-jet Blower), but the first pokerless producer-gas machines are giving the same perfection of service today as they have done continuously for the past twelve years.

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